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SOIL-MOISTURE FLUCTUATIONS UNDER TWO PONDEROSA PINE STANDS IN NORTHERN ARIZONA[1]

by

Waldo S. Glock,[2] Edward M. Gaines, and Sharlene R. Agerter

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INTRODUCTION

Soil moisture, or the lack of it, is of great significance in the complex of factors that influence tree growth. A knowledge of soil-moisture fluctuations can lead to a better understanding of tree growth, of seedling establishment, and of effective rainfall. Soil moisture is one important step closer to the physiological regime within the plant than is the rain that falls upon the soil surface.

The purpose of the work here described was to trace the course of soil-moisture fluctuations for a minimum interval of 3 years at two dissimilar stations within the ponderosa pine forest of north-central Arizona.

This report records the soil-moisture data and suggests possible interpretations, including influences on tree growth.

LITERATURE

A comprehensive survey of the literature that would touch upon soil moisture in all its phases is impractical in the present report. Although Kittredge (1948)[3] presents a comprehensive review of the complex relationships involved, the work of several other men should be mentioned also.

In 1931, Pearson (pp. 63-72) published soil-moisture records taken at different depths in various forest types adjacent to the San Francisco Peaks in northern Arizona. Soil-moisture determinations during the warm seasons of 1918, 1919, and 1920 were made at intervals of 2 weeks to a month. Pearson reasoned that soil-moisture profiles for the 3 years were not typical because of unusual weather conditions. The shallowness of root systems emphasized by Pearson is of great importance in both phases of the study--soil moisture and tree growth.

Colman (1944), Colman and Bodman (1944), and Schiff and Dreibelbis (1949) emphasized the speed of infiltration and percolation. Byram and Doolittle (1950), Fielding and Millett (1941), and MacDougal(1921) point out that trees respond to an increase in soil moisture directly and almost immediately. According to Byram and Doolittle, the time required by a shortleaf pine to recover from a lack of water seemed "to be determined only by the time required for the water to reach the roots."

The resumption of growth after soil-moisture replenishment, reported by several workers, illustrates the close relationship between soil moisture and tree growth when temperature does not preclude growth. In Australia, bursts of growth followed soaking rains in summer and autumn (Fielding and Millett 1941). Herman (1956) reported similar observations on Arizona junipers. In South Carolina, during the 1951 drought, the upper 66-inch layer of soil was at its wilting point most of August; trees did not grow until the September rains brought on a vigorous response (Hoover et al. 1953). In California, a pine that had ceased growing in midsummer resumed growth after it was irrigated (MacDougal 1923).

[3] *Names and dates in parentheses refer to Selected Bibliography, p. 25.*

DESCRIPTION OF LOCALITIES

Two sites, 15 miles apart, were chosen for the installation of soil-moisture stations, one well within the zone of ponderosa pine forest (Fort Valley Station, fig. 1); the other near its lower border (Walnut Canyon Station, fig. 2). Both stations were located within 200 yards of cooperative weather stations where daily readings were taken.

Both stations were located under crowns of mature pines which would intercept some rain or snow. Both had substantial litter layers which would retain water equivalent about 1-1/2 times their dry weight (Kittredge 1948, p. 194). Hence light rains would not affect soil moisture, particularly during dry seasons. Herbaceous cover at both stations was sparse.

The forest interior station (Fort Valley) was located in a virgin stand of mature ponderosa pine on a mesalike surface underlain by basaltic lava of the San Francisco volcanic field. The site, just west of the Fort Valley Experimental Forest headquarters at 7,350 feet elevation, is near the southwest base of the San Francisco Peaks which are some 6 miles distant. No surface drainage to or away from the station was apparent; subsurface drainage (percolation) appeared to be vertical.

The lower forest-border station (Walnut Canyon) was in a mixed stand of mature ponderosa pine with a very scattered understory of pinyon, juniper, and oak brush, on a nearly flat surface underlain by arenaceous limestone (Kaibab). The study plot was near the north boundary of Walnut Canyon National Monument, at 6,750 feet elevation on the Coconino Plateau, 14 miles southeast of San Francisco Peaks. Drainage to or from the station was slight or nonexistent; percolation appeared to be vertical.

The soils recorded at the time the stations were installed differed as shown in the following descriptions:

FORT VALLEY: 4 inches of litter and humus above mineral soil.

Soil depth (Inches)	
0-18	Fine textured
18-34	Fine textured, with numerous small rocks
34-46	Cinders
46-60	Fine textured, with small rocks
60-84	Fine textured
84-96	Soil with cinders

Figure 1.--The soil-moisture station at Fort Valley, located in the forest interior. The three trees plus the stile form the corners of the plot.

WALNUT CANYON: 2 inches of litter and humus above mineral soil.

Soil depth (Inches)	
0-15	Fine textured, roots numerous below 4 inches
15-22	Fine textured, with a few small rock fragments
22-34	Fine textured, with rocks
34-36	Soil with abundant roots
36-42	Firm, fine textured soil, difficult to penetrate

The two layers -- 22 to 34 inches and 36 to 42 inches -- appeared to be decomposed rock rather weakly cemented. Material was reduced to powder when brought up by auger.

On the whole, the two stations differed in (1) relation to the ponderosa pine zone, (2) elevation, (3) proximity to the San Francisco Peaks, (4) underlying bedrock, (5) depth of soil, and (6) nature and amount of precipitation.

INSTRUMENTATION

A "stack" of plaster of paris soil-moisture blocks was installed at each station, March 10-11, 1955. At the Fort Valley station, a vertical hole, 96 inches deep, was bored with a 6-inch hand post-hole auger. At Walnut Canyon, a similar hole was bored, but stopped at 42 inches after boring 6 inches in a half-cemented "hardpan" layer. In each case, the soil was separated so that each layer could be replaced in its original position.

A soil-moisture block was placed on the bottom in each hole and the soil replaced and packed, to approximately original density, around and over the block until the level for the next higher block was reached. This procedure was repeated until all blocks were placed and the hole filled.

The wires leading from the blocks were kept apart and spiraled around the hole as it was filled. At the top of the hole, the wires were led to the side and dipped about 2 inches before they emerged from the soil. These precautions minimized the chance that water could collect on and run down the lead wires. The ends of the wires were brought into a small wooden box for protection.

Readings were taken on Bouyoucos available-moisture meters, one at each station (table 3, p. 27). The meters determined percentage of available moisture, and thus re-

Figure 2.-- The soil-moisture station at Walnut Canyon, located near the lower forest border. These mature ponderosa pines are being used for core sampling.

corded relative rather than absolute amounts. A reading of zero on the meter corresponded approximately to the wilting point of the soil. During long periods when zero percent was recorded, soil moisture may have decreased considerably below the wilting point, and large amounts of moisture might have been required to restore the soil moisture to the wilting point before positive readings could be recorded. Long periods of high readings -- 75 to 90 percent -- may have represented field capacity of some soil layers.

The completed plot at Fort Valley (fig. 3) was laid out as shown in figure 4. A barbed wire fence enclosed the 16-foot-square area so that a walkway was left between fence and plot; the box holding the wire terminals could be reached without passing over the area immediately above the plaster blocks.

At Walnut Canyon the same ground plan was used except that the shape had to be adjusted to the position of the trees. At both stations, the stack of plaster of paris blocks was placed within the zone of lateral roots, and presumably the soil was completely occupied by roots. Depths of the various plaster blocks at the two stations were as follows:

Block number	Fort Valley (Inches)	Walnut Canyon (Inches)
1	4	4
2	8	8
3	12	12
4	18	18
5	24	24
6	36	36
7	48	42
8	60	
9	70	
10	84	
11	96	

TIME OF READINGS

Plans specified weekly readings throughout the entire year except when snow covered the lead-in boxes. In case of probable rain, a reading was to be taken within a few hours prior to the rain. Readings were to be taken also within 24 hours after a rain of 0.15 inch or more and daily thereafter until readings at all depths returned to or below values of the last reading before the rain. Although it was not always possible to follow the plans as laid out, readings were taken rather frequently for 4 years. It was noted that considerably more than 0.15 inch of rain was required to affect readings, even at the 4-inch depth.

At Fort Valley, readings were taken on five consecutive days during and after heavy rains in June 1955. Daily readings were taken in several series during July-August 1955 and July 1956. In many cases, however, readings were taken at intervals longer than a week and a few at less than a week.

At the Walnut Canyon station, there were many cases of consecutive daily readings in connection with rainfall. From June 15 to August 31, 1955, readings were taken daily, and over rather long periods they averaged oftener than weekly. The periods during which readings were taken are summarized in the following tabulation:

			Number of readings
FORT VALLEY:			
1955	May 27	- Oct. 24	67
1956	Mar. 30	- Dec. 21	56
1957	Jan. 5	- Oct. 31	44
	Nov. 4	- Dec. 3	2
1958	Jan. 14		1
	Apr. 28	- July 14	6
	Aug. 4	- Nov. 12	14
WALNUT CANYON:			
1955	May 31	- Dec. 29	104
1956	Jan. 16	- Sept. 6	80
	October		3
	Dec. 13		1
1957	Jan. 7	- Dec. 24	65
1958	Jan. 17		1
	Feb. 12		1
	June 17	- July 31	5
	Aug. 8		1
	Sept. 5	- Dec. 16	11

Two points must be recognized with respect to initial and final meter readings: In 1955, time was required for the moisture

Figure 3.--Completed soil-moisture station at Fort Valley showing plot arrangement. (See figure 4.)

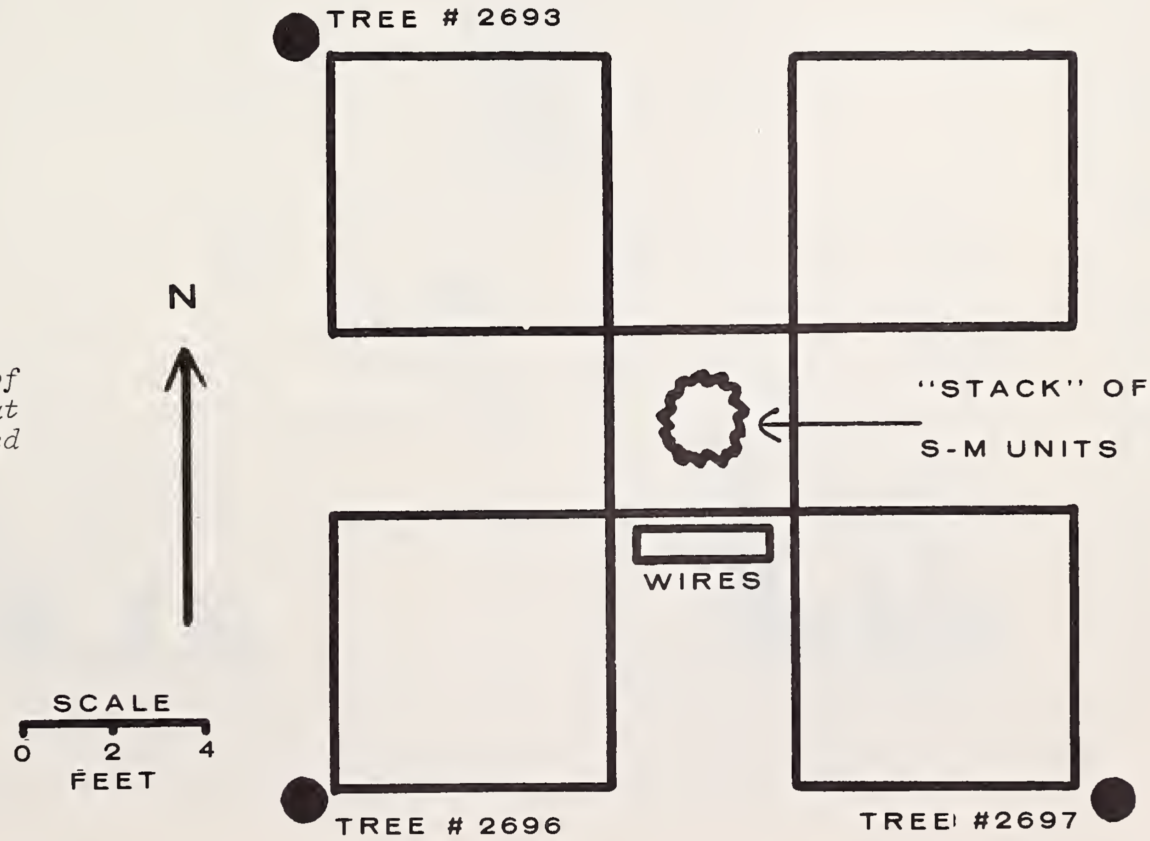


Figure 4.--Arrangement of soil-moisture plot at Fort Valley as pictured in figure 3.

blocks and the repacked soil column to reach equilibrium with adjacent soil and for roots to reoccupy the disturbed soil column. Meter readings were continued into October 1959 at Fort Valley and into September 1960 at Walnut Canyon. But since the plaster blocks deteriorate after 3 years of use, results became erratic. For that reason records for 1959 and 1960 were not considered in this report.

RAINFALL REGIMES

Figure 5 gives annual rainfall and monthly minimums, maximums, and averages for 4 years of precipitation at Fort Valley and Walnut Canyon. Within the span of 4 years large fluctuations were found. Such fluctuations are typical of long-term records at these stations and others of the area.

Table 1 brings together information concerning the precipitation amounts and characteristics daily, monthly, and annually at Fort Valley and Walnut Canyon for the 4 years, 1955-58. Average annual rainfall at Fort Valley for the 4 years was 22.28 inches; at Walnut Canyon, 16.88 inches. In details from month to month, the two stations recorded marked differences at certain times, especially in the summer. For example, in August 1955, rain fell at both stations on 8 days; on 10, it rained at Fort Valley only; and on 6, it rained at Walnut Canyon only. The amounts of rain varied greatly on any 1 of the 8 days when rain fell at both stations. During the 10 days with rain only at Fort Valley, 4.99 inches of rain fell; during the 6 days with rain only at Walnut Canyon, 0.67 inch fell. Summer rain on the Coconino Plateau is thunderstorm type, and may be quite localized on a particular day.

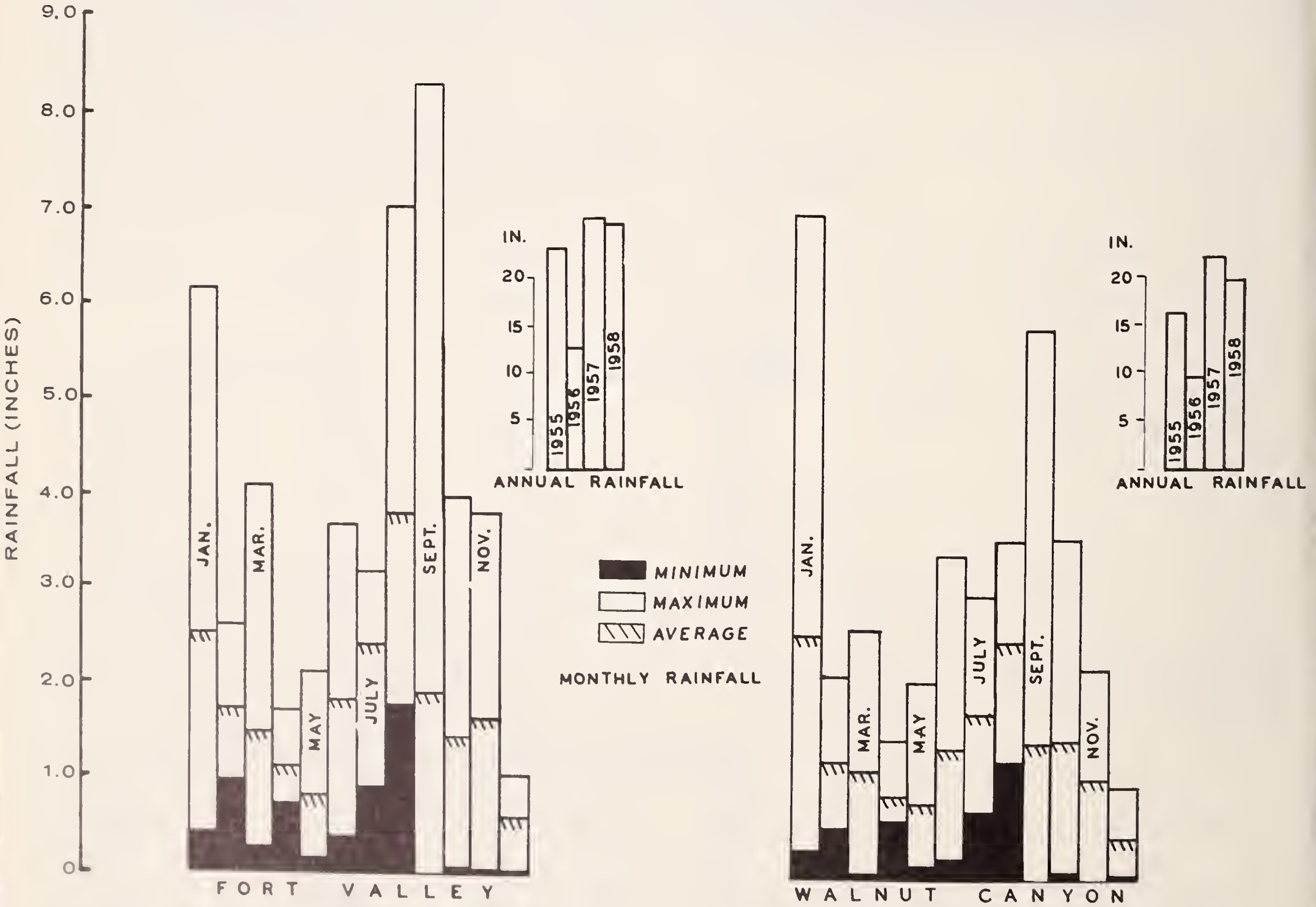


Figure 5.--The maximum, average, and minimum monthly precipitation at Fort Valley and at Walnut Canyon, plus yearly average for the four years under study.

Month	1955					1956					1957					1958				
	Amount of precipitation	Days when precipitation was--				Amount of precipitation	Days when precipitation was--				Amount of precipitation	Days when precipitation was--				Amount of precipitation	Days when precipitation was--			
		0.10 inch or more	0.50 inch or more	1.00 inch or more	Total		0.10 inch or more	0.50 inch or more	1.00 inch or more	Total		0.10 inch or more	0.50 inch or more	1.00 inch or more	Total		0.10 inch or more	0.50 inch or more	1.00 inch or more	Total
	Inches	- - - Number - - -				Inches	- - - Number - - -				Inches	- - - Number - - -				Inches	- - - Number - - -			
FORT VALLEY																				
January	3.23	9	1	0	11	2.50	6	1	0	8	6.17	15	4	1	16	0.42	1	0	0	4
February	2.34	5	2	1	7	1.00	4	0	0	6	1.06	3	1	0	5	2.63	5	3	1	7
March	.30	1	0	0	2	.47	1	0	0	3	1.31	4	1	0	9	4.10	11	3	0	14
April	.74	2	0	0	2	1.12	5	0	0	7	1.02	5	0	0	6	1.73	4	2	0	5
May	.43	3	0	0	5	.17	1	0	0	2	2.12	9	0	0	11	.85	4	0	0	5
June	3.69	2	2	2	2	1.89	1	1	1	2	1.34	3	1	0	4	.38	1	0	0	1
July	3.24	7	2	1	12	2.61	8	1	0	11	2.85	9	1	0	15	.92	2	1	0	6
August	7.05	11	5	2	14	1.80	7	0	0	10	2.42	7	0	0	13	4.09	10	3	0	19
September	T	0	0	0	0	T	0	0	0	0	T	0	0	0	0	8.35	11	7	3	13
October	.09	0	0	0	2	.82	3	0	0	5	3.96	9	5	0	11	.77	3	0	0	5
November	1.32	5	0	0	5	.05	0	0	0	1	3.81	7	3	1	9	1.38	3	2	0	4
December	1.15	3	1	0	3	.54	2	0	0	2	.85	3	0	0	5	.05	0	0	0	1
Total	23.58	48	13	6	65	12.97	38	3	1	57	26.91	74	16	2	104	25.67	55	21	4	84
WALNUT CANYON																				
January	1.78	5	1	0	7	1.47	7	0	0	11	6.93	10	6	2	12	.36	2	0	0	3
February	1.18	4	1	0	7	1.17	2	1	0	4	.51	2	0	0	3	2.13	4	2	1	9
March	.04	0	0	0	1	.32	1	0	0	4	1.66	3	2	0	4	2.68	9	1	0	12
April	.60	2	0	0	2	.92	3	0	0	7	.63	2	0	0	2	1.44	5	1	0	5
May	.65	3	0	0	3	.12	1	0	0	1	2.02	8	0	0	10	.46	1	0	0	2
June	3.38	3	1	1	3	1.34	2	1	1	2	1.10	2	0	0	2	.20	1	0	0	1
July	2.98	6	1	1	11	2.13	7	1	0	10	1.25	6	0	0	7	.70	3	0	0	7
August	3.18	8	2	0	14	1.23	5	0	0	7	2.12	6	1	0	11	3.55	7	2	1	14
September	.07	0	0	0	1	T	0	0	0	0	0	0	0	0	0	5.76	12	4	1	16
October	.05	0	0	0	1	.38	1	0	0	2	3.58	7	2	2	8	1.03	5	0	0	7
November	1.25	3	1	0	4	T	0	0	0	0	2.20	6	1	0	6	1.22	3	1	0	3
December	.98	1	1	0	1	.42	1	0	0	1	.33	2	0	0	3	.02	0	0	0	1
Total	16.14	35	8	2	55	9.50	30	3	1	49	22.33	54	12	4	68	19.55	52	11	3	80

The pattern of precipitation at the two stations differs in total amounts, in distribution details, and distribution amounts (table 3, p. 27). Records have been kept at Fort Valley for 47 years; at Walnut Canyon, 11 years. But at both stations, 1956 showed the lowest amount of precipitation recorded.

FORT VALLEY STUDIES

Infiltration and Percolation

The infiltration and percolation of soil moisture within the root zones of trees may occur in a matter of hours or days. Penetration below 12 to 24 inches may require 1 to 3 weeks. Many of the recorded fluctuations of soil moisture, however, did not lend themselves to simple and direct interpretations because of the complexity of the interrelationships among interception of precipitation by tree crowns, litter, and humus; infiltration; percolation; wetting; intensity of rainfall; cumulative rainfall; evaporation; transpiration; physiological activities of the plant cover; instrumental variations; and the long period between some measurements.

At Fort Valley in 1955 (fig. 6) moisture-meter readings fell steadily from the first reading in May until June 4, and presumably continued to fall until June 13. The rains of 3.69 inches on June 13-14 were followed by a pronounced increase in moisture readings at 4- and 24-inch depths. At intermediate depths, the increase of the already high moisture content was slight, and the percolating water passed through to the 24-inch depth. The added soil moisture penetrated to 36 inches between June 17 and 21.

Soil moisture at the 24-inch depth decreased from July 9 to August 15, whereas at the 36-inch depth it decreased until August 24. The rains of July and August up to the 15th totaled 6.40 inches in 22 days of rain. Apparently the soil moisture from these rains, aided by 2 inches on August 15 and 17, passed through the shallow depths where soil moisture was at or near field capacity, and caused a rapid rise at 24 inches during August 16-17. Nine days later the soil moisture at 36 inches suddenly increased from near zero to 75 percent of available moisture. It is to be noted, however, that this rapid rise occurred within a day after a rain of 1.28 inches on August 24.

In 1956, two contrasting situations stand out at Fort Valley (fig. 7). A rain of 1.65 inches on June 30 penetrated 8 inches in 3 days, and had very little effect at 12 inches. In spite of the heavy rain, soil moisture at 4 inches rose only from 4 to 22 percent, at 8 inches from 4 to 12 percent, and at 12 inches from 2 to 5 percent of field capacity. Percolating water did not reach 18 inches. In contrast, the frequent, small summer rains that started July 13 and accumulated 2.61 inches during the remainder of the month had no effect until after July 26. The heaviest rain of the series, 0.69 inch, came July 29; soil-moisture readings of July 30 showed a precipitous rise from zero or near zero on July 26 to 34 to 75 percent. Summer rains did not penetrate so far as 24 inches. Thus, the early single heavy rain had little effect, whereas a series of lighter rains climaxed by a moderately heavy one increased soil moisture markedly to a depth of 18 inches.

There were three situations of note at the Fort Valley station during 1957 (fig. 8). On January 5, all levels were at zero readings. Precipitation of 0.64 inch, January 4 to 6, augmented by 1.97 inches on January 8 and 9, brought a decided increase in the readings of January 11 to a depth of 18 inches. The increase had reached 24 inches at the time of the next reading, January 18; 36 inches by February 18, which was the first reading since January 25; and 48 inches on February 25. Subsequent precipitation of 2.78 inches from January 21-30 and 1.06 February 18-24 may have contributed to driving the moisture to those depths.

A second situation in 1957 occurred in connection with summer rains. The steady decline of soil moisture that began toward the end of June was arrested in an irregular fashion, to the 12-inch level only, by 4.10 inches of rain that fell on 18 different days from July 14 to August 13. The largest fall was 0.57 inch on July 18. Rains of 0.83 inch on August 25-27 brought a slight rise of soil moisture at 4 inches only.

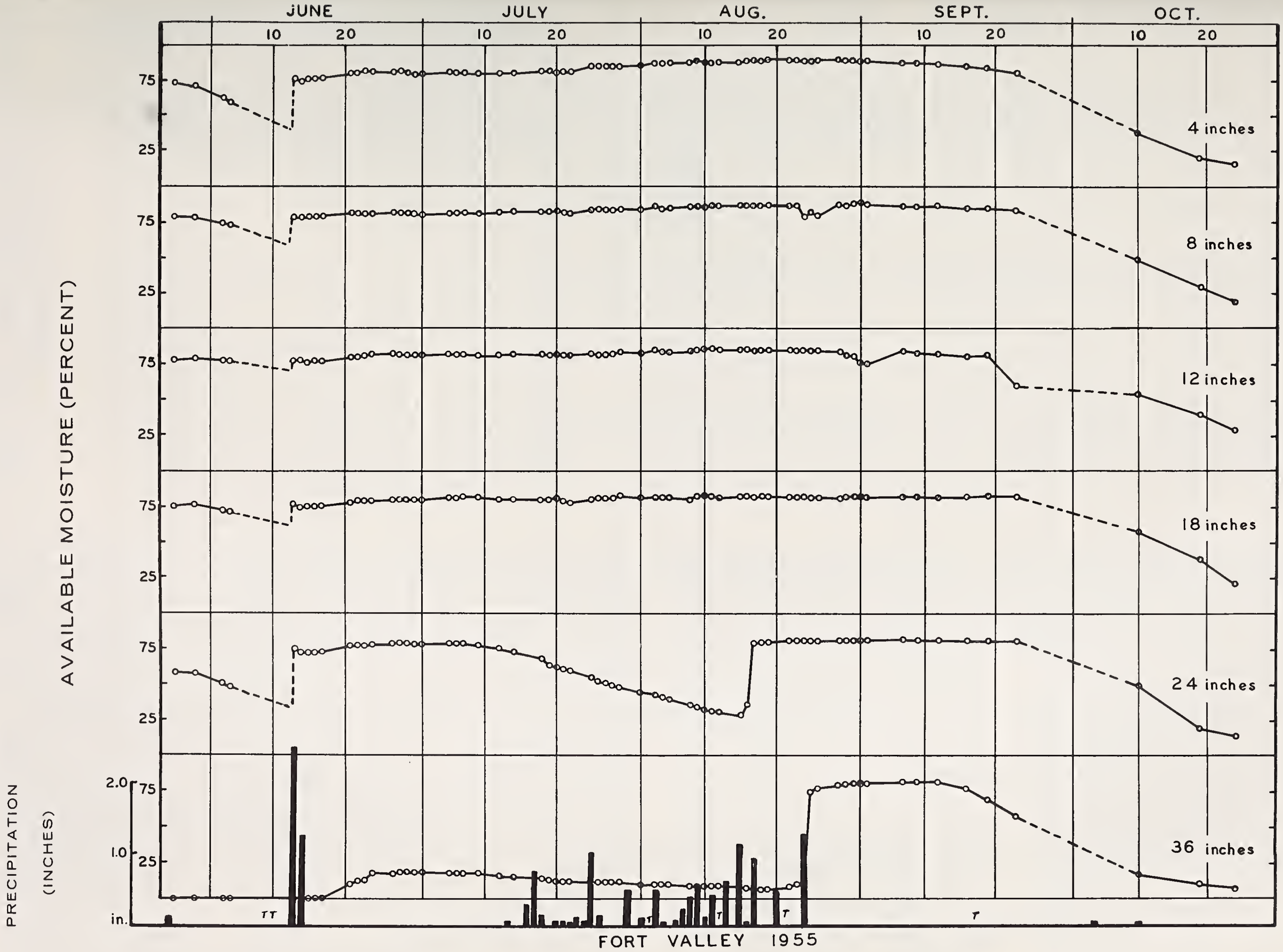


Figure 6.--Plotted soil-moisture readings and daily precipitation at Fort Valley, June-October 1955, to 36 inches. Readings at greater depths were at or near zero except at 96 inches, which registered about 18 percent at all times.

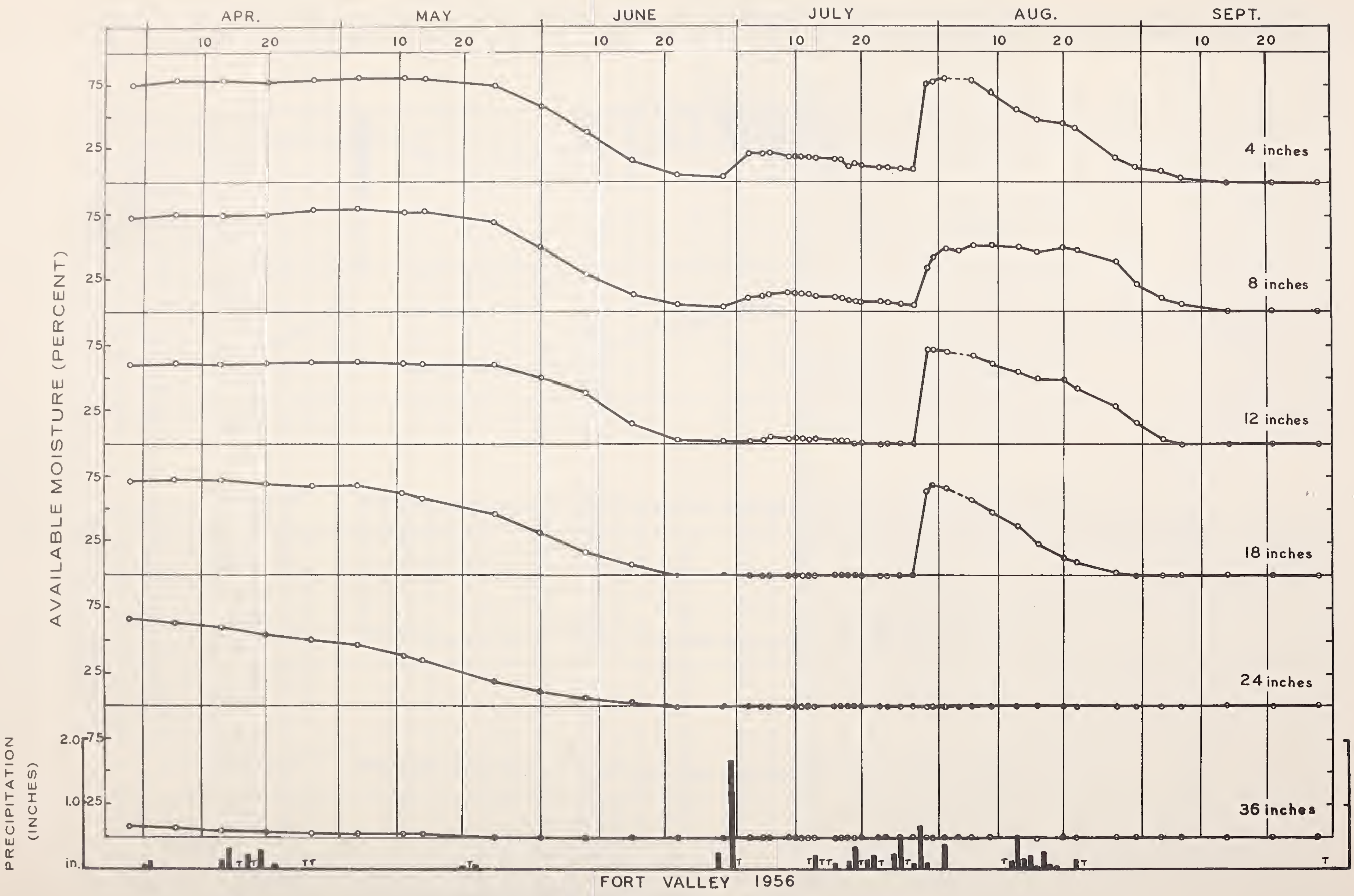


Figure 7.--Plotted soil-moisture readings and daily precipitation at Fort Valley, April-September 1956, to 24 inches. Readings taken October-December registered zero at all times. Readings below 24 inches were at or near zero for the entire period except at 96 inches, which showed about 12 percent.

The third situation of 1957 occurred in connection with the October rains. Available soil moisture had declined from July through September to near zero at all depths except 96 inches. The 1.83 inches of rain October 11-13 brought an abrupt rise in the readings of October 14 to the 18-inch depth. Readings at the 24-inch level remained at zero until after October 31. Additional rains, culminating in 2.06 inches on November 3-4, apparently caused a rise to 81 percent on November 4. These same rains may have caused the slight rise at the 18-inch depth. A reading taken a month later, December 3, showed that a slight rise in soil moisture had occurred at 36 inches at some time between readings. No additional moisture was detected at 48 inches.

A total of 17.50 inches of precipitation was recorded from October 1, 1957, to April 30, 1958. On April 28, soil moisture was high throughout the full 96-inch profile, except for the 36-inch level. Attempts to explain this disparity would be largely speculative. By contrast, 10.97 inches during the same period on 1956-57 raised soil moisture only through the 48-inch depth, and 7.65 inches in 1955-56 only through the 24-inch depth. The long-term average precipitation for this 7-month period is between 13 and 13-1/2 inches.

Two other situations in 1958 are worthy of comment, one in connection with single light rains of early summer and the other with continued rains of late summer (fig. 9). The rain of 0.38 inch on June 22 after 22 rainless days did not halt the decline of soil moisture as measured 4 days later. It may not even have penetrated the litter layer. The rain of 0.58 inch on July 24, after another 32 rainless days, was not apparent in the soil on August 4. Down to 36 inches, available soil moisture was very low or near zero on August 4. The accumulated rains of late July and early August caused a rise in soil moisture by August 11, slight at the 4- and 8-inch levels but pronounced at the 12- and 18-inch levels. The additional heavy rains of early September apparently forced moisture through to the 24-inch depth, and later, in irregular pattern, to 48 inches.

Soil-Moisture Patterns

Soil-moisture fluctuations at Fort Valley were not uniform from year to year. With two wet seasons a year, two general periods of high soil-moisture content might be expected. They do not necessarily occur, as there is great variation in precipitation among seasons. In 1955, soil moisture remained high at the first four levels through the early summer dry season and did not begin to decrease until well into the autumn dry season. The July decline of soil moisture at 24 and 36 inches was reversed sharply in August, a result perhaps of the percolating waters from summer rains. Possibly roots did not effectively reoccupy the disturbed soil column until late summer.

Total precipitation at Fort Valley during 1956 was the lowest in 47 years of record. Soil moisture was high only through the 24-inch depth after the winter wet season and declined into the early summer dry season. Summer rains increased soil moisture sharply down to 24 inches. By mid-September soil moisture was at zero percent, where it remained presumably until the start of the next winter wet season. The curve of soil moisture during 1956 traces a double-crested graph to match a double rainy season.

The beginning of the winter wet season in January 1957 restored soil moisture to a high level through the 48-inch depth, where it remained until well into the early summer drought. The summer rains came as frequent but generally light showers, and the general decrease of soil moisture continued into the autumn dry season, with only a slight and irregularly placed temporary delay in August down to 12 inches. Apparently interception, evaporation, and transpiration generally exceeded rainfall. October-November rains restored soil moisture to rather high levels -- down through 24 inches. Thus, the soil moisture of 1957 stands in an intermediate position between 1955, with one time of decided dearth of soil moisture, and 1956 with two marked intervals of low moisture.

The year 1958 had two times of declining soil moisture as did 1956, but in contrast with 1956 the early summer drought was longer and not so intense, and the rise in soil moisture due to the summer rains was greater and continued much longer. Heavy September rains restored soil moisture through the 48-inch level.

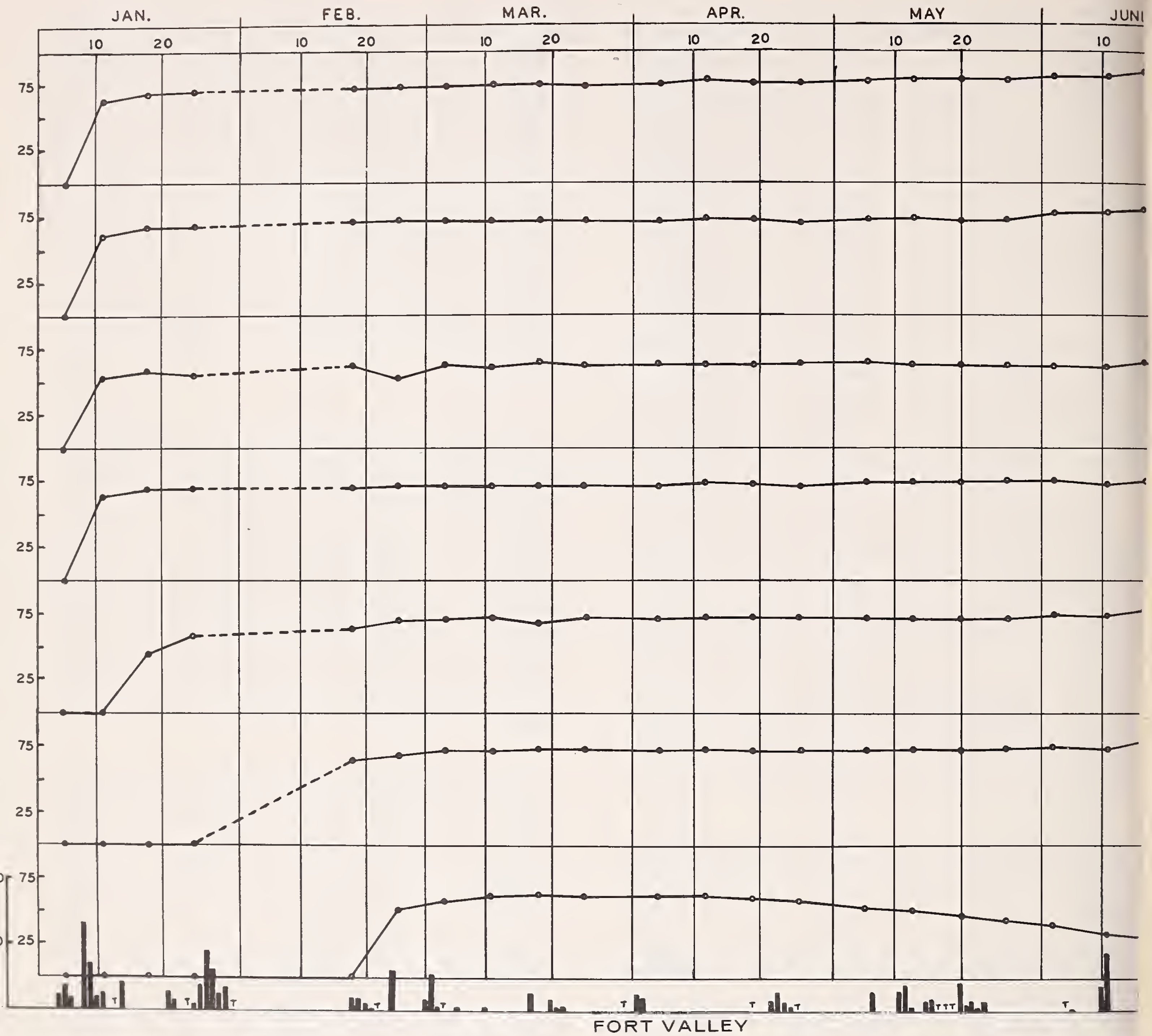
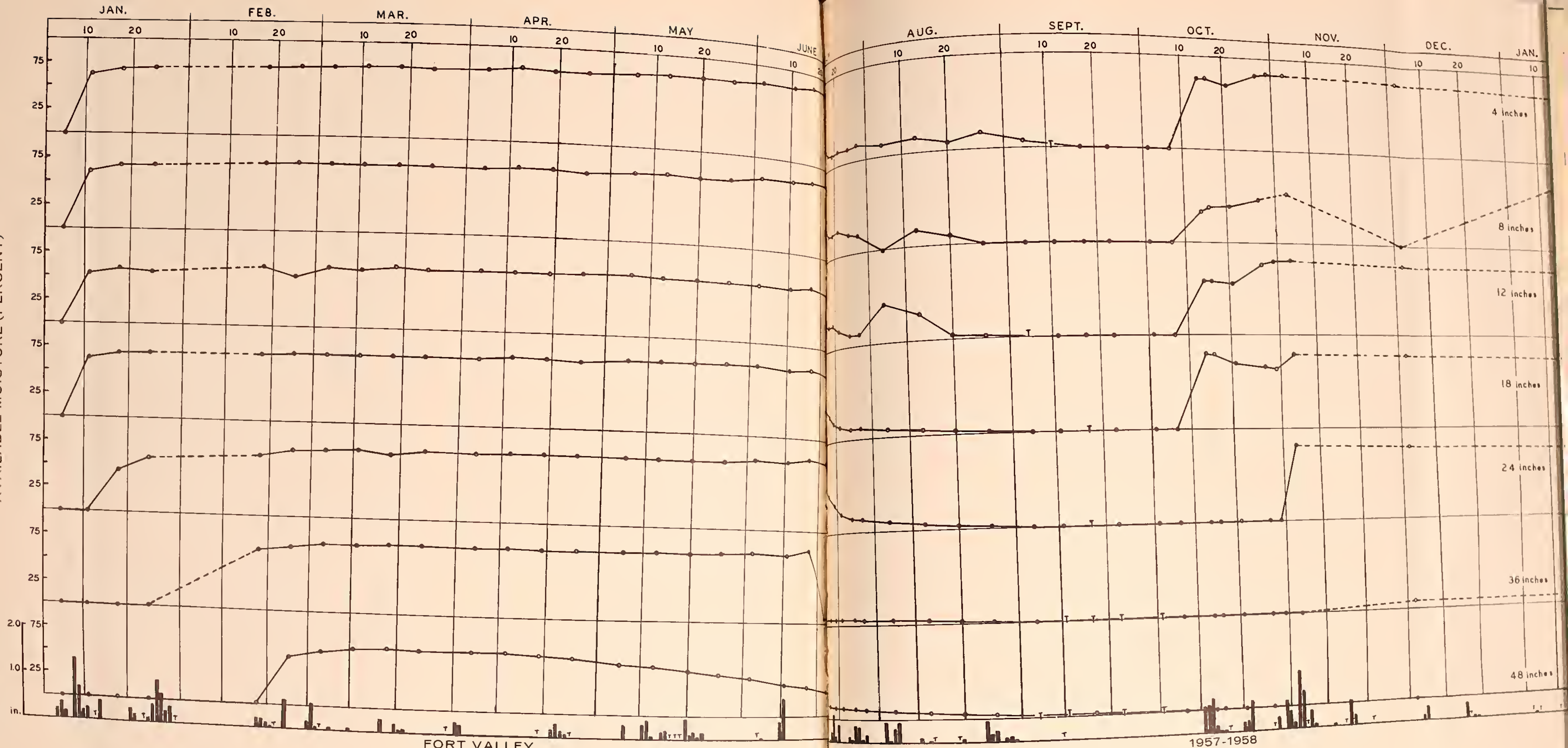


Figure 8.--Plotted soil-moisture readings and daily precipitation at Fort Valley, January 1957-January 1958, to 48 inches. Readings below 48 inches were at or near zero except at 96 inches, which fluctuated around 10 percent.



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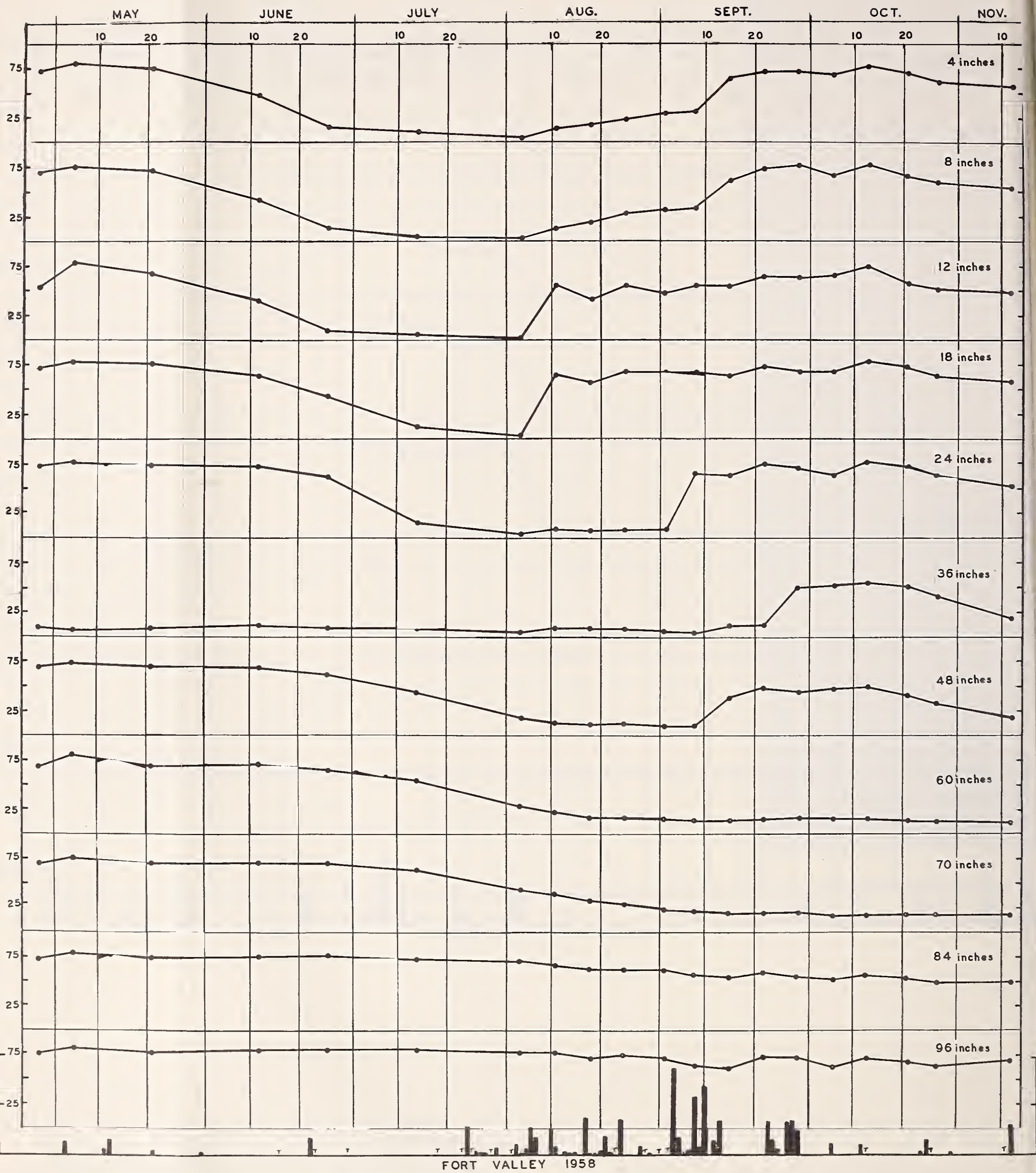


Figure 9.--Plotted soil-moisture readings and daily precipitation at Fort Valley, May-November 1958, to 96 inches.

At Fort Valley, soil-moisture records for the 4 years, 1955-58, differed from each other in detail. Winter precipitation comes at a time when vegetation in general is dormant and transpiration from conifers at a minimum. The precipitation is effective in recharging the moisture in the deeper layers of soil. Summer precipitation, coming at a time when vegetation is active and transpiration at a maximum, rarely penetrates to levels where it contributes to the deep soil-moisture reservoir.

WALNUT CANYON STUDIES

Infiltration and Percolation

At Walnut Canyon in 1955 (fig. 10), the rain of 3.05 inches on June 13 had a spectacular influence at 4, 8, and 12 inches. Arrival of the moisture at 8 inches was delayed not more than 2 days (no readings on June 14). It raised the moisture level at 12 inches from near zero to 80 percent, starting within 2 days and continuing through 11 days. In July, with a fair amount of soil moisture remaining at the upper three levels (possibly because roots had not yet reoccupied the disturbed soil column), the response to rainfall on three successive days was more gradual than in June. The summer rains appear to have had only slight effect at 18 inches. Speed of depletion of moisture of the upper three soil levels and its dependence on the immediate rains are well illustrated by the June-September graphs. In contrast with rapid responses of soil moisture to rainfall at shallow depths during the summer, precipitation of 0.62 inch on November 13 and 0.33 inch on November 14 had not affected the 4-inch depth by November 15. Precipitation of November and early December apparently did not penetrate to the 12-inch depth.

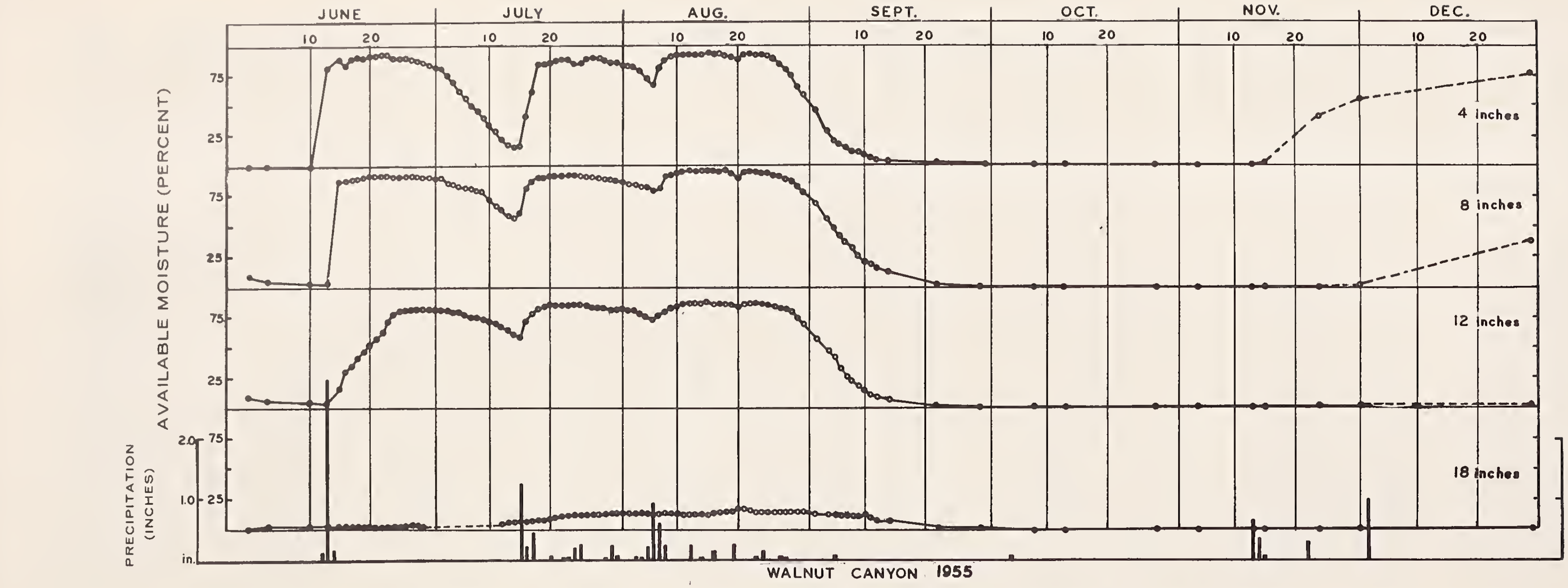
Soil moisture increased through February and March 1956 (fig. 11), because of the January-February precipitation, but only through the 12-inch depth. Readings of February 18, the first since January 28, showed an increase of soil moisture at the 4- and 8-inch depths. At the 12-inch depth, the increase appeared at the next reading on February 28.

The summer rains of 1956 consisted of a heavy rain in late June and scattered rains in July-August. Their effects did not reach to 8 inches. Rains of 1.44 inches on June 28-30 caused an increase of soil moisture at 4 inches, from zero on June 27, to 20 percent on June 30, and 75 percent on July 2. Here, a heavy rain produced a rapid response in soil-moisture replenishment at shallow depths.

Nearly 1.6 inches of rain scattered over an interval of 11 days in late July caused a steady and moderate increase of soil moisture at 4 inches only. The light, scattered rains of August may have delayed somewhat but did not prevent the decrease of soil moisture to zero percent at 4 inches even before the rains ceased.

In 1957, soil moisture increased rapidly and to a great extent in connection with precipitation of January and with rains of October-November, and increased slightly and more slowly, at 4 inches only, in connection with those of May-June (fig. 12). Precipitation of 1.72 inches on January 8 increased soil moisture at 4 inches from zero on January 7 to 75 percent on January 9. At 8 inches, soil moisture showed an increase between January 10 and 12, and reached a high point on January 16. The increase at 12 inches started 3 days later than at 8 inches. Precipitation of late January appeared to have passed through the upper levels, high in soil moisture at the time, and to have reached the 18- and 24-inch levels between February 8 and 11. Three additional days were required for the soil moisture to pass from 24 inches to 36 inches. Increase at 42 inches was more gradual; maximum was reached in late March.

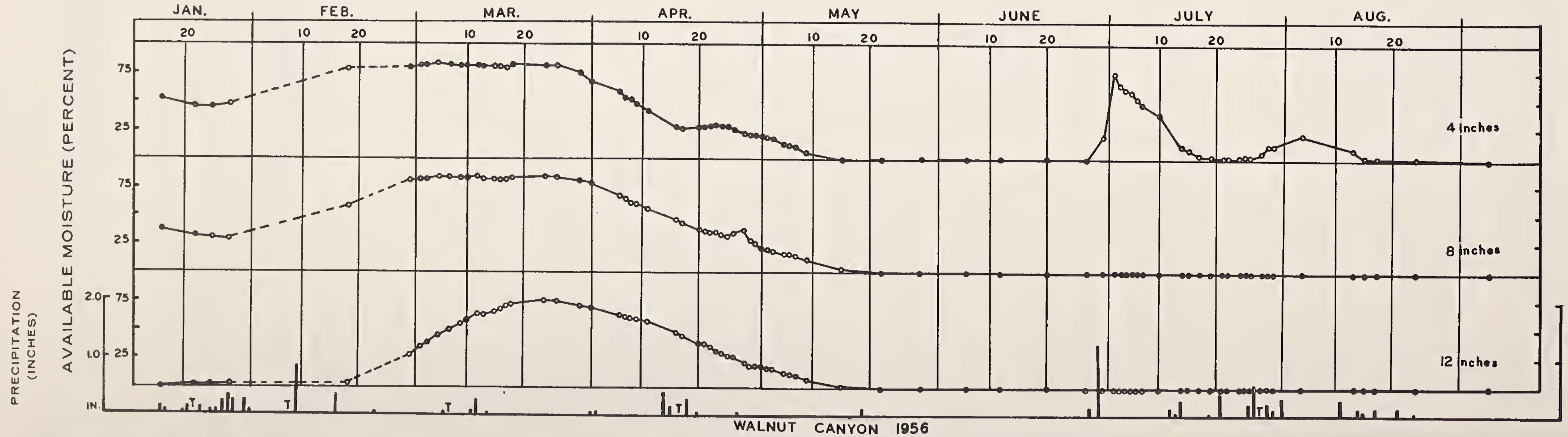
The rains of October-November 1957 penetrated effectively to the 24-inch level. Rains of 1.50 inches on October 11-12 had no effect at 4 inches until the reading dates, October 14-16, after which there was a gradual increase in soil moisture, to a maximum on November 4. Apparently the fall rains did not affect soil moisture below the 4-inch depth until the storms of the 4-day period, October 31 to November 3, which totaled 2.53 inches, increased soil moisture at the 8- and 12-inch depths from zero on November 1 to 80 percent on November 4. Available soil moisture at 18 inches remained at zero at least until November 7, 3 days after the peak at 12 inches. The peak at 18 inches was recorded on November



PLOTTED SOIL-MOISTURE READINGS AND DAILY PRECIPITATION AT WALNUT CANYON.

Figure 10.--June-December 1955, to 18 inches. Readings at greater depths near zero except at 42 inches, where they fluctuated around 17 percent until October when they started to decrease.

Figure 11.--January-September 1956, to 12 inches. Readings remained at zero until December 13. Readings at greater depths were at or near zero except for 42 inches, which fluctuated around 14 percent until the end of May when it also dropped to near zero.



15, and at 24 inches on November 20. At greater depths the rains of autumn had a very slight effect.

Gaps in the record and long intervals between readings prevent detailed interpretation of infiltration and percolation in 1958. Readings of August 8, 1958, showed zero available moisture above 42 inches (fig. 13). Eighteen rains from August 2 through September 4 totaled 4.70 inches, with one rain of 1.56 inches on August 17. On September 5, the 4-inch level showed 56 percent available moisture; the 8-inch, 28 percent; and the 12-inch, 3 percent. The 2.50 inches of rain from September 23-28 apparently passed through the already moist 4- and 8-inch levels with slight and moderate effects, and brought the 12-inch reading up sharply in the readings of September 29. No increase in soil moisture was detected at 18 inches until October 8; 4.68 inches of rain had fallen since September 4. Here, as in former years, summer rains penetrated only the shallow layers of soil.

Soil-Moisture Patterns

The soil-moisture regime at Walnut Canyon appeared more regular than that at Fort Valley, and dry periods were longer and more intense. When soil-moisture readings were begun at Walnut Canyon in early June 1955, available moisture was near or at zero percent down to 36 inches. A single heavy rain and the general summer rains brought a rapid rise in soil moisture, which then remained high until late August. Again, we may presume that roots did not reoccupy the disturbed soil column until late summer. Low soil moisture during early summer and autumn droughts separate intervals of high soil moisture of the two rainy seasons, thus giving a soil-moisture regime, at shallow depths, consistent with what one would expect from the precipitation.

In 1956, the winter precipitation increased soil moisture down to only 12 inches. The late spring-early summer dearth of soil moisture continued into January 1957 except at 4 inches, where the summer rains brought a sharp but temporary increase.

Soil-moisture fluctuations of 1957 bear little resemblance to those of 1955 or of 1956. A late-summer increase is entirely lacking, presumably because July-August rains were light and scattered. High available soil moisture of January-March began to decline in April, and with only a brief hesitation at shallow depths reached zero or near zero percent during July. No perceptible change occurred until the rains of October and early November brought a rapid increase down to 24 inches. Rains that fell in July and August did not cause a crest in soil moisture.

Thus at Walnut Canyon the 3 years of 1955-57 present three types of soil-moisture regimes: 1955 with its summer abundance of soil moisture bounded by a lack of soil moisture before and after the summer rainy season; 1956, a very dry year, with its slight response to summer rains; and 1957, a year of much early and late rain, with no distinct summer crest of soil moisture when rain was below average.

The abundance of soil moisture in late 1957 continued into the winter of 1958. When the record began again in June-July 1958, readings were near or at zero. The increase that came later was not a "typical" summer increase, but was displaced from July-August to September-October.

At Walnut Canyon as at Fort Valley, amounts of annual precipitation varied and the distribution changed from year to year. On long-time averages, two crests of soil moisture would be expected each year, one during winter and the other during summer. For any particular year the general rule does not necessarily apply, as the 4 years of record illustrate.

COMPARISON OF SOIL-MOISTURE FLUCTUATIONS

The variations in soil moisture from year to year are generalized in figure 14 for Fort Valley and in figure 15 for Walnut Canyon. Winter crests are more uniform and persistent than summer crests. Annual totals, period totals, or even monthly totals of precipitation can form no constantly safe guide to the amounts of soil moisture available at any specified time. Integration of data on size and

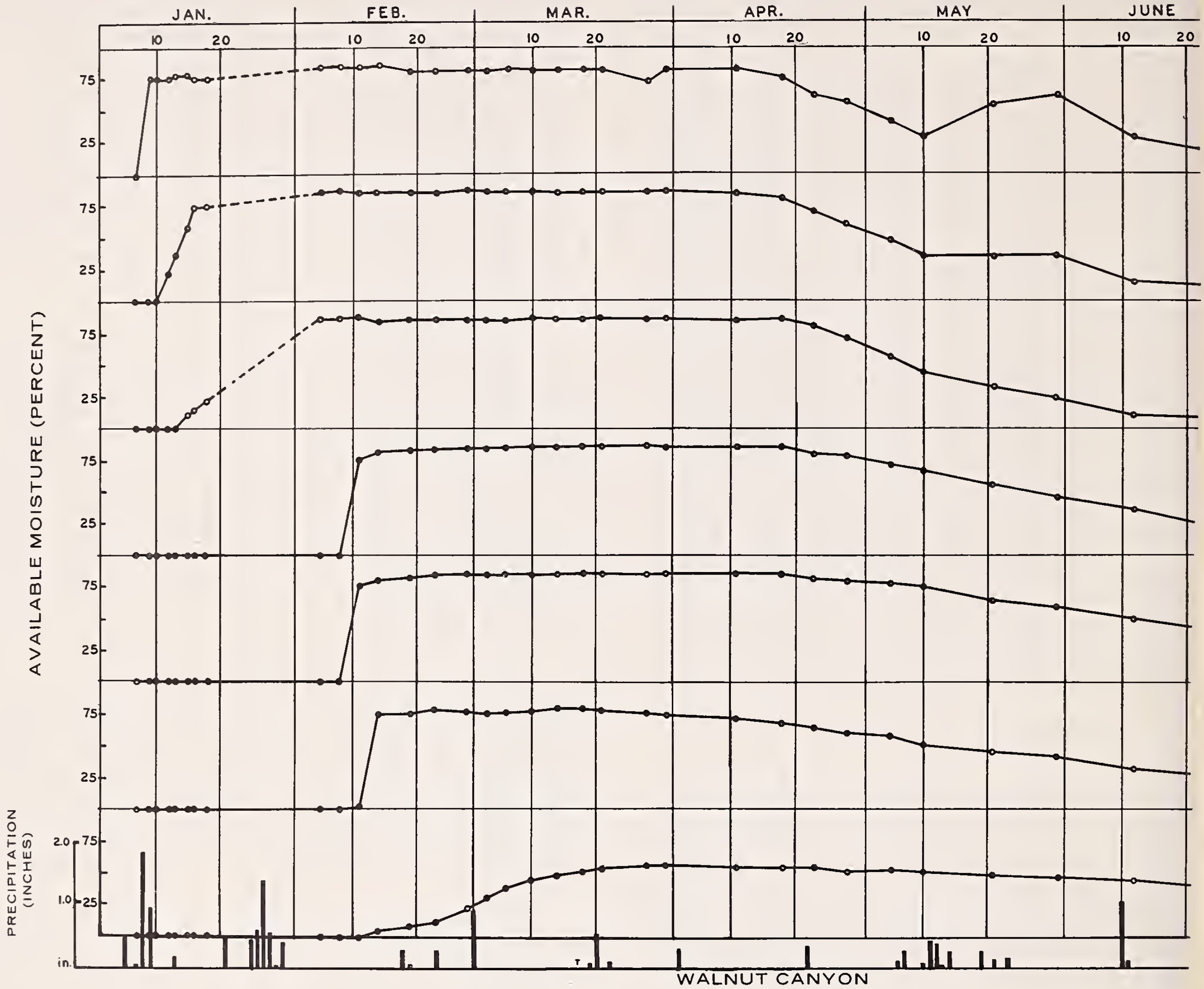


Figure 12.--Plotted soil-moisture readings and daily precipitation at Walnut Canyon, January 1 February 1958, to 42 inches.

spacing of storms, adjusted for season and existing soil moisture, might provide a better guide.

Insofar as records are available, the gross features of the graphs on figures 14 and 15 are much the same. Soil moisture at Walnut Canyon is not so plentiful or so long continuing as at Fort Valley. Smaller amounts of precipitation fall on shallower soil. There are differences in detail. A high percentage of soil moisture at Fort Valley does not always indicate a high percentage at Walnut Canyon.

One point of special significance to hydı ogy stands out in a comparison of summer winter percolation. Summer rainfall selc penetrated through the shallow soil layer: the deep layers. Only winter precipitat penetrated to a depth sufficient to recha the deep-soil reservoir, and this only v ample precipitation. The tendency for mc ture to remain constant in the deep layers soil probably means that few, if any, ro exist at these levels. In fact, the rate of mo ture depletion at different depths might used to interpret the effective depth of r systems.

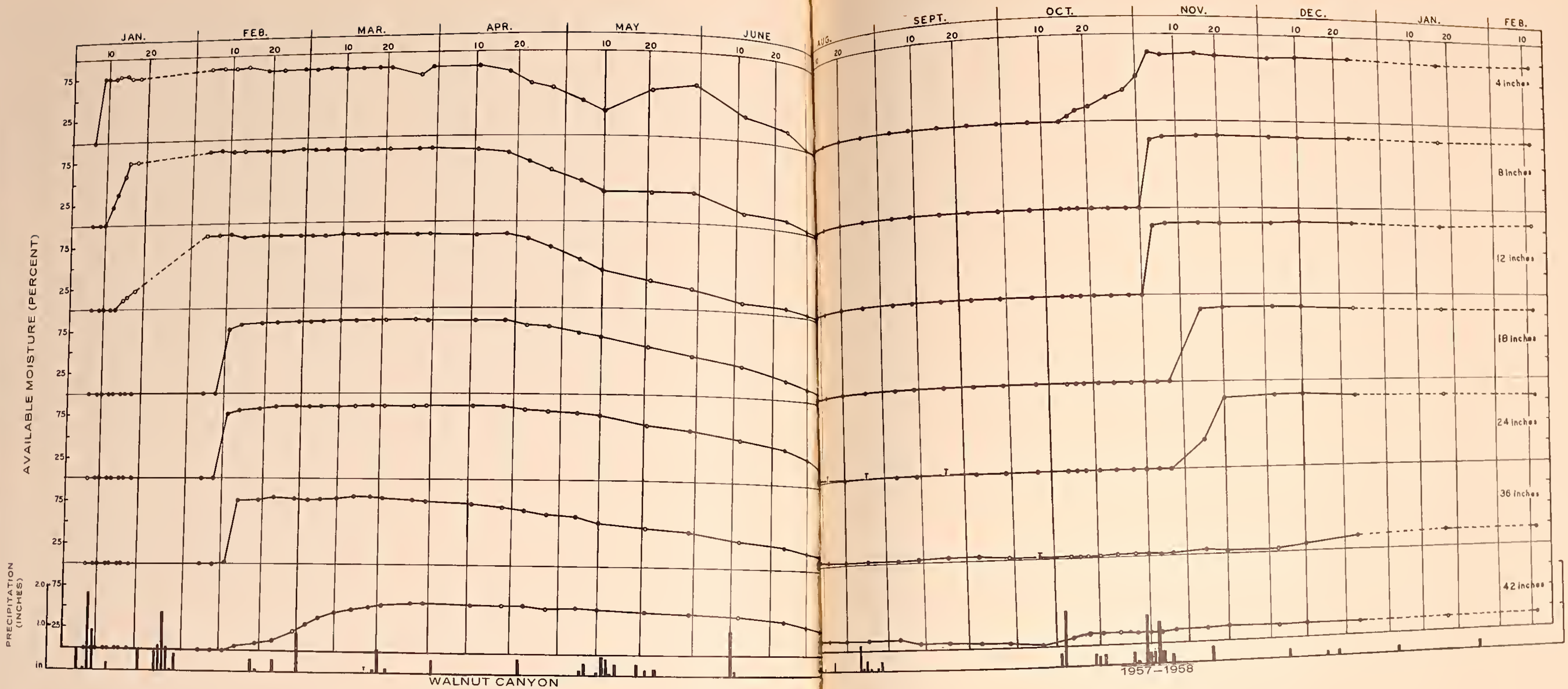


Figure 12.--Plotted soil-moisture readings and daily precipitation at Walnut Canyon, January 1957-February 1958, to 42 inches.

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One point of special significance to hydrology stands out in a comparison of summer and winter percolation. Summer rainfall seldom penetrated through the shallow soil layers to the deep layers. Only winter precipitation penetrated to a depth sufficient to recharge the deep-soil reservoir, and this only with ample precipitation. The tendency for moisture to remain constant in the deep layers of soil probably means that few, if any, roots exist at these levels. In fact, the rate of moisture depletion at different depths might be used to interpret the effective depth of root systems.

SOIL MOISTURE AND TREE GROWTH

The role of soil moisture in relation to tree growth and the problems inherent in a study of these relationships are brought to a focus in the apt title: "Trees also need water at the right time and place" (Hayes and Buell 1955). Pearson (1918, 1924, 1931, 1950) mentioned the importance of the growing season and the position of feeder roots. Time growth begins in the spring is largely attributed to temperature. Moisture no doubt contributes to amount of growth and time of cessation.

The frostless period at the Fort Valley and Walnut Canyon stations commonly extends from early June to late September (Pearson 1931, p. 19), but at Walnut Canyon the period is several days longer. From information given by Pearson (1931, pp. 22-31) it may be inferred that mean maximum, mean minimum, and mean monthly temperatures are several degrees lower at Fort Valley than at Walnut Canyon.

The position of feeder roots bears a distinct relationship to fluctuations of soil moisture. According to Pearson (1931, p. 64), "the

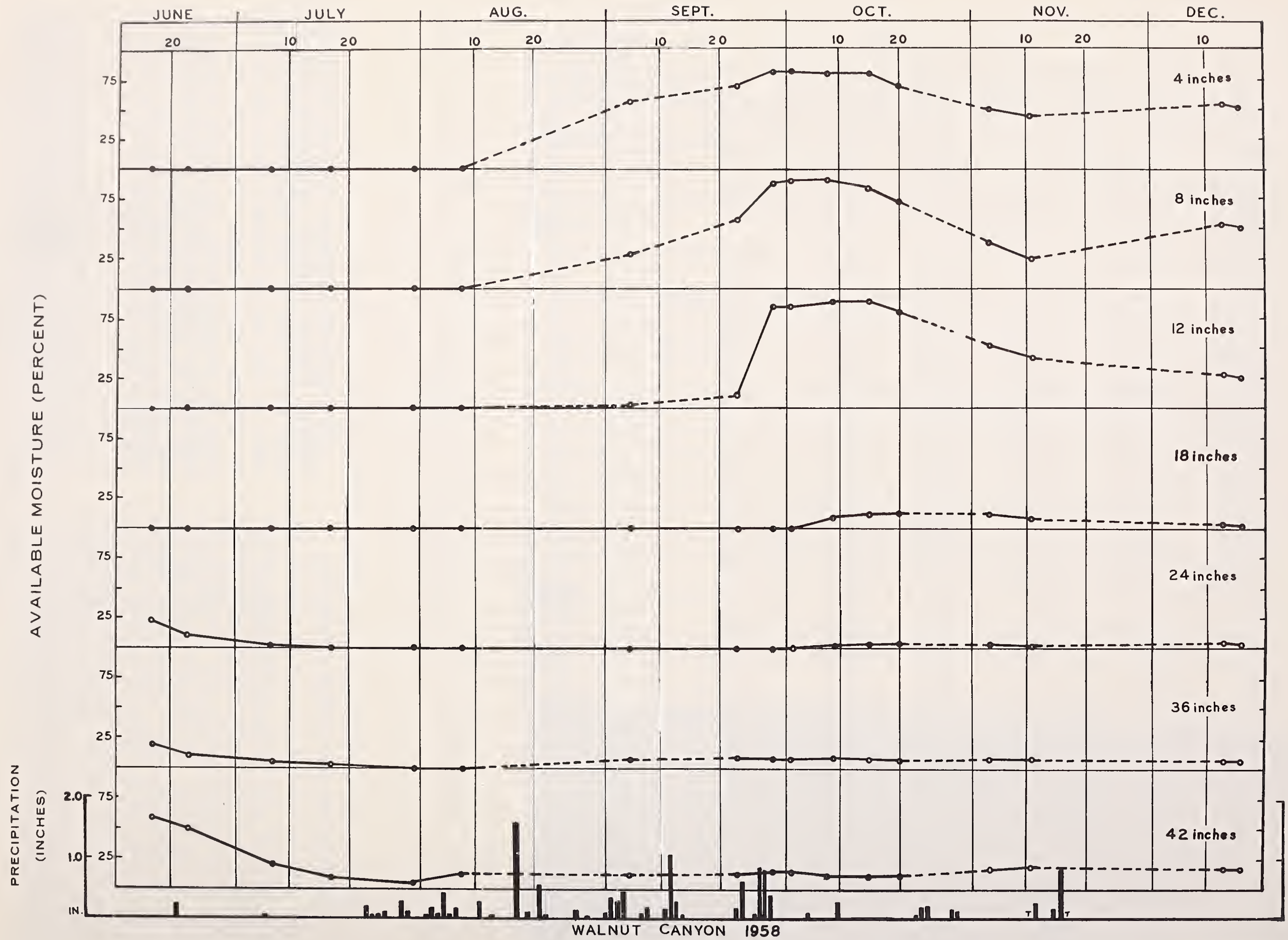
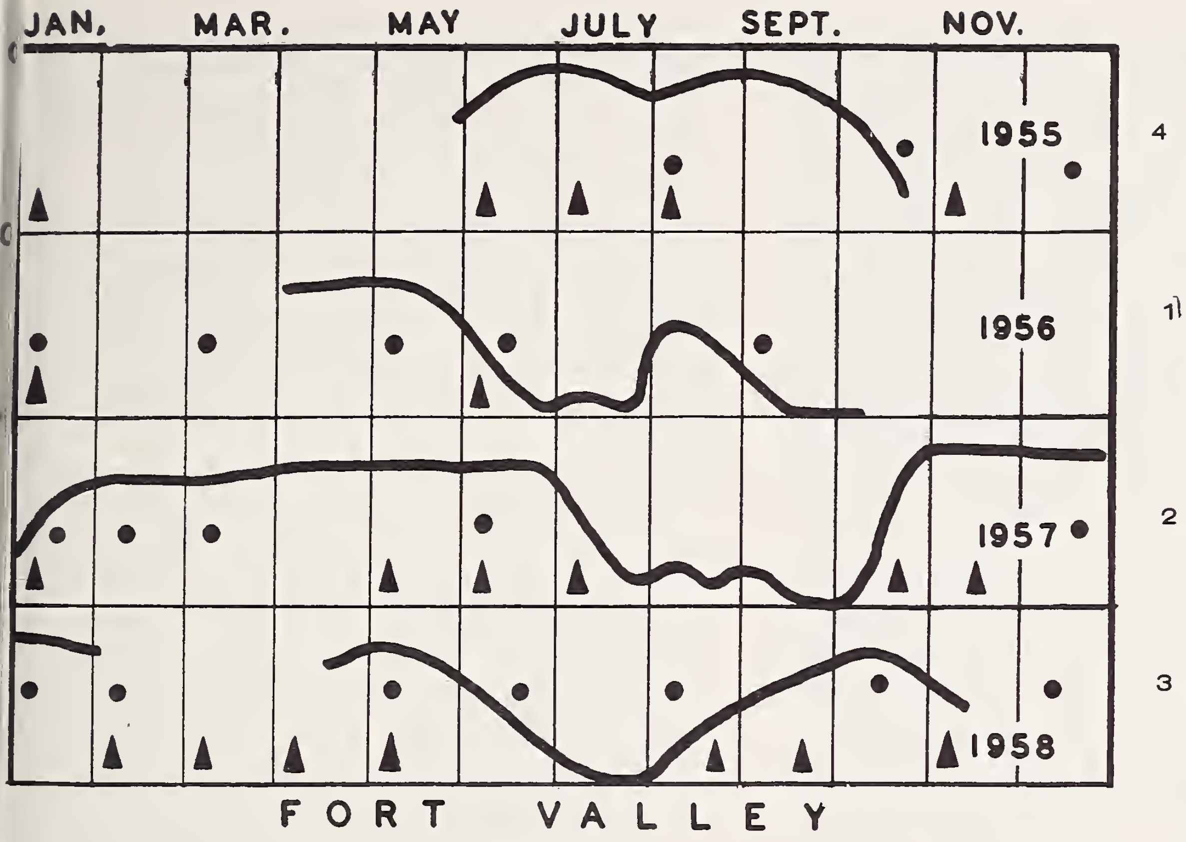


Figure 13.--Plotted soil-moisture readings and daily precipitation at

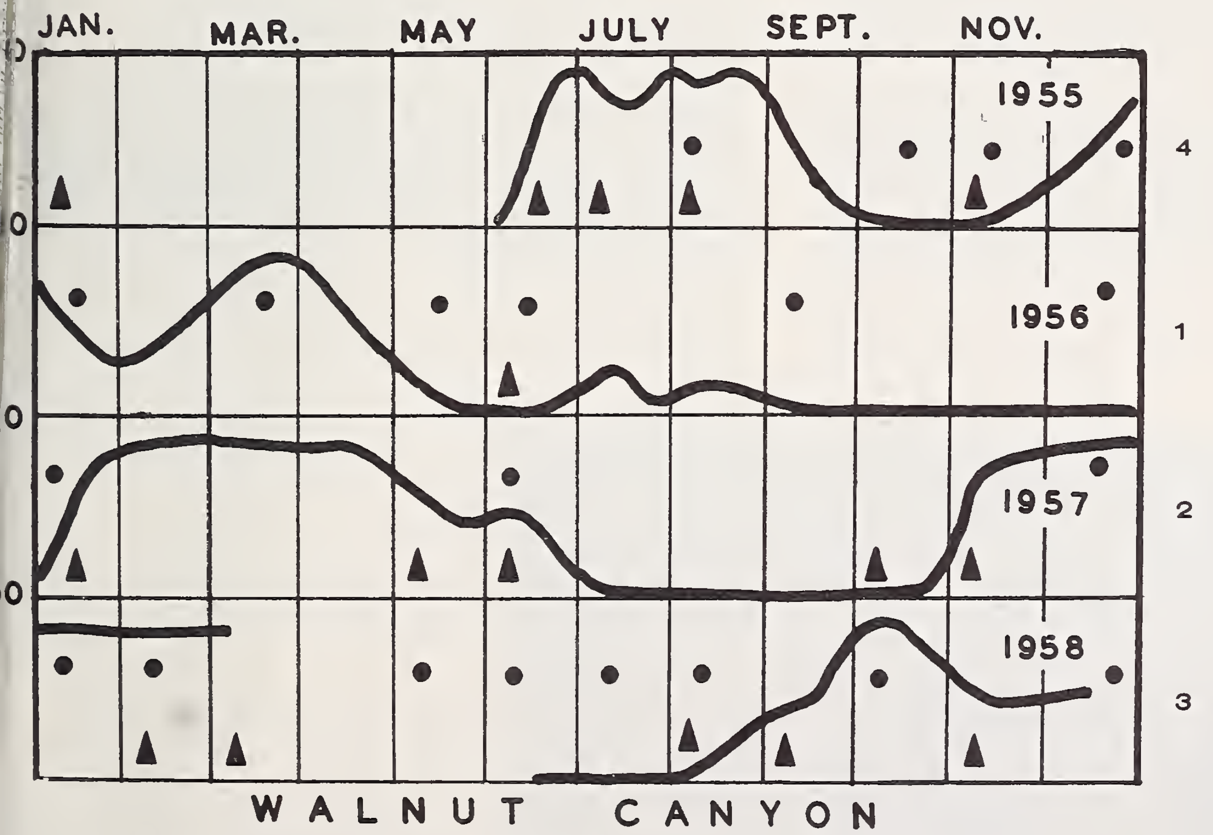


▲ PRECIPITATION ABOVE NORMAL

● TEMPERATURE ABOVE NORMAL

Figure 14.-- FORT VALLEY

Variations in soil-moisture regimes from year to year and months of above normal temperature and precipitation. Numbers at right margin are increasing thickness of growth layers.



▲ PRECIPITATION ABOVE NORMAL

● TEMPERATURE ABOVE NORMAL

Figure 15.-- WALNUT CANYON

great mass of feeders lies within 2 feet of the surface." Under certain soil conditions roots may penetrate to a depth of 4 feet, or slightly more. Observations of windthrown trees and of root systems exposed in cinder pits over a period of many years have supported Pearson's statements. Figure 16 shows the flat lateral root system of a windthrown ponderosa pine just west of the Fort Valley station headquarters. Although the flat mass, 6 to 18 inches thick, might be thinner than the average, it illustrates the typical root system observed not only in the vicinity of the soil-moisture stations, but also extensively throughout the ponderosa pine zone of northern Arizona. The great mass of feeder roots are no doubt confined to the shallow layers where moisture is frequently available during the active growing season. The rate and amount of summer moisture depletion at different depths probably indicated the effective depth of root systems.

Elongation, or tip growth begins in May, proceeds rapidly in June, then slows and ceases early in July (Pearson 1924, p. 203; 1931, pp. 19, 99). Our observations for the past 12 years have shown that tip and needle growth at a certain time have been more advanced in general at Walnut Canyon than at Fort Valley.

Figure 17 gives percentage of radial growth by certain dates of the years 1954-61 for the two groups of ponderosa pine averaged for each station. Incomplete growth of a year was compared to completed growth of the sam year of all cores taken subsequently. Henc from 1954 to 1961 there was a decreasin number of growth layers from which to obtai the percentage of completion.

Individual trees show considerable varia tions from the average; cores taken at bot stations showed that the range in percentag of completeness appeared to be less at Walnu Canyon than at Fort Valley, as follows:

	Percent
Fort Valley:	
July 28, 1956	62-100
August 14, 1959	46-100
July 9, 1960	21- 60
August 1, 1960	38- 87
July 3, 1961	16- 56
July 29, 1961	47-100
Walnut Canyon:	
July 25, 1956	28-100
Aug. 12, 1959	85-100
July 8, 1960	83-100
June 29, 1961	61- 96
July 24, 1961	84-100

Cores taken at both stations showed growth had been completed by October 6, 1961.

Perhaps the most important fact shown by figure 17 is the percentage of the year's growth attained: a higher percentage had been completed by a certain date at Walnut Canyon than at Fort Valley.

Figure 16.-- "Pancake" root system of a windthrown ponderosa pine west of Fort Valley station headquarters.

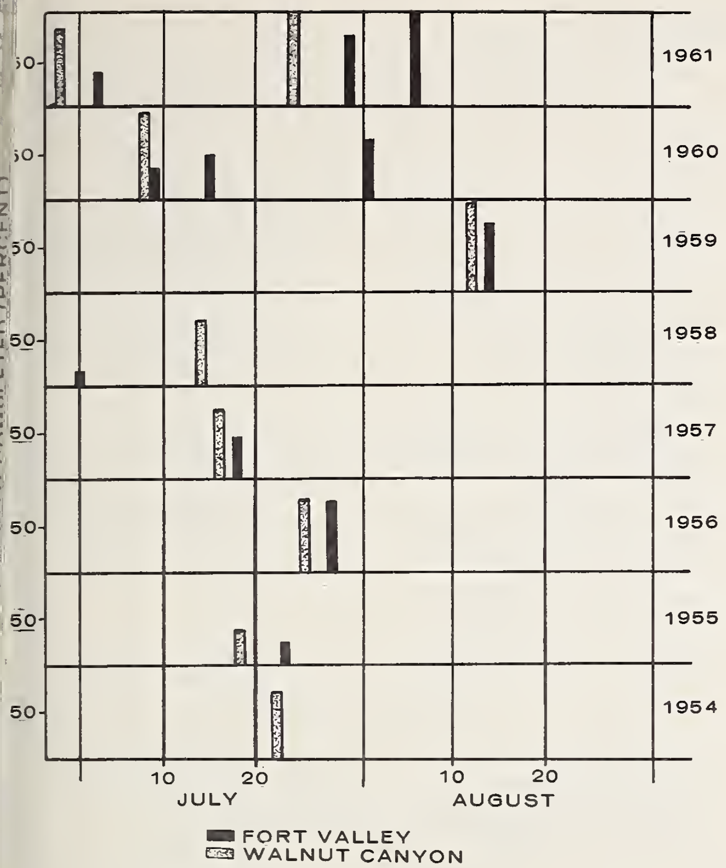


Figure 17.--
Percentage of growth completed by various dates in July and August for trees at Fort Valley and at Walnut Canyon.

Diameter growth (Pearson 1924, pp. 203-204; 1931, p. 19) begins the latter part of May and is practically complete by September 1. This does not mean that growth must continue that long, that it must be continuous, or that it must be parallel in time or amount at Walnut Canyon and Fort Valley. A test made the first part of July at Walnut Canyon showed diameter growth in a mature ponderosa pine equaling the average growth-layer thickness of the previous 10 years. There was no evidence of densewood (summerwood). In contrast a test made at the same time at Fort Valley showed only one to two rows of new cells, which indicated that growth had just begun. This was not an isolated instance.

Many ponderosa pines at Fort Valley, Walnut Canyon, and several other localities in the vicinity of Flagstaff have been observed and cored since 1949. Before 1949, cores were taken every 2 or 3 years; since 1958, cores have been taken two or three times each year. Since the soil-moisture stations were established, trees whose root zones surrounded the plaster blocks, and two others in the immediate vicinity, were added to those sampled. The number of cores used in the averages for each year varies from 25-39 for 1955 to 17-25 for 1958. Except for 1956 little relationship was found between growth-layer thickness and precipitation, either annual or period. July-August rainfall appears to have a somewhat closer relationship to growth-layer thickness than do the other rainfall periods. The relationship is neither close enough nor sufficiently prolonged to be more than suggestive.

Information for Fort Valley and Walnut Canyon is summarized as a matter of convenience for each year, beginning with the year of the thinnest growth layer (table 2).

The length of record, 4 years, is inadequate for more than tentative conclusions. When readings began the end of May 1955, the plaster blocks may not have quite attained equilibrium with the soil and its moisture, and tree roots may not have reoccupied the disturbed soil until even later in the summer. Some of the blocks may have failed as early as 1958.

Temperatures during the growing season apparently were not prime controlling factors in the thickness of the growth layers. The year 1955, which produced the thickest growth layer of the period 1955-58, had temperatures below normal January to July. August was above normal. In 1956, which produced the thinnest growth layer of the period, temperatures were above normal May-June and below normal July-August.

Soil moisture appears to be more directly related to growth than is temperature. The thickest growth layer, 1955, was formed during a summer of abundant soil moisture and of precipitation double that of the other years. During the year of the thinnest growth layer, 1956, summer soil moisture was scant and the limited winter soil moisture was depleted rather early. In 1957, the year of the next to thinnest growth layer, summer soil moisture was scant and winter soil moisture was depleted a month later than in 1956. Both 1956 and 1957 had low summer precipitation compared with 1955; the winter precipitation of

Table 2.--Temperature, precipitation, and soil moisture as related to growth-layer thickness at Fort Vallĕy and at Walnut Canyon, 1955-58

Growth layers	Year	Average temperature	Precipitation	Soil moisture
		FORT VALLEY		
Thinnest; 0.45 mm. 75 percent of growth layer completed by July 28	1956	Jan.-Apr.--Alternately above and below normal May-June--Above July-Aug.--Below Sept.--Above Strong drying winds in May	Annual: Least in 4-year period, 1955-58 Jan.--Slightly above normal Feb.-May--Much below June--Much above July--Slightly below Aug.--Much below Sept.--Trace Oct.-Dec.--Much below	Began decline in mid-M near zero by June 20; v low until late July; brief crest first week of Augu down to 18-inch depth; decline to zero reading early September
Next to thinnest; 0.54 mm. 44 percent of growth layer completed by July 18	1957	Jan.-Mar.--Much above normal Apr.-May--Much below June--Above July-Sept.--Below	Annual: Highest in 4-year period, 1955-58 Jan.--Much above normal Feb.-Apr.--Much below May-June--Much above July--Slightly above Aug.-Sept.--Much below Oct.-Nov.--Much above	Began decline in late Ju low by late July; not rep ished until October
Next to thickest; 0.64 mm. 16 percent of growth layer completed by July 1	1958	Jan.-Feb.--Above to much above normal Mar.-Apr.--Much below May-June--Above July--Slightly below Aug.--Above Sept.--Below	Annual: Next to highest in 4-year period, 1955-58 Jan.--Much below normal Feb.--Normal Mar.--Much above June-July--Much below Aug.-Sept.--Above Sept.--Nearly 5 times normal	Began gradual decline la May; low by end of June; some recharge began fir half of August to be follo by more in September
Thickest; 0.65 mm. 73 percent of growth layer completed by July 23	1955	Jan.-July--Below to much below Aug.--Slightly above Sept.--Slightly below	Annual: Next to least in 4-year period, 1955-58 Jan.--Above normal Feb.--Normal Mar.-May--Below Mar.--Much below June--More than 5 times normal July-Aug.--Above to much above Sept.-Oct.--Much below Nov.--Normal Dec.--Below normal	Abundant all summer
		WALNUT CANYON[1]		
Thinnest; 0.19 mm. 78 percent of growth layer completed by July 25	1956	Alternately above and below normal Jan.--Much above May-June--Above July-Aug.--Below Sept.--Above Strong drying winds in May	Annual: Least in 4-year period, 1955-58 Jan.-May--Below normal Mar.--Much below June--Nearly 5 times normal July-Dec.--Much below	Began decline in late Ma zero by late May; rechar at 4-inch depth only, end June and slightly first we of August; rapid decline t zero in each case
Next to thinnest; 0.49 mm. 74 percent of growth layer completed by July 16	1957	Jan.-Mar.--Much above normal Apr.-May--Below to much below June--Above July-Sept.--Near normal	Annual: Highest in 4-year period, 1955-58 Jan.--Nearly 4 times normal Feb.-Apr.--Below to much below May-June--3 to 4 times normal July-Sept.--Below to much below Oct.-Nov.--Above normal	Began decline in late Apr low or zero by July 1; no recorded recharge until late October-early Noven
Next to thickest; 0.58 mm. 69 percent of growth layer completed by July 14	1958	Jan.-Feb.--Much above normal Mar.-Apr.--Below May-Aug.--Above Sept.--Normal	Annual: Next to highest in 4-year period, 1955-58 Jan.--Much below normal Feb.-Mar.--Much above Apr.-May--Below June--Above July--Much below Aug.-Sept.--Above to much above	At or near zero in mid-Ju possibly some recharge to 8-inch depth late August a certainly early September greater recharge to 12-in depth late September
Thickest; 0.63 mm. 39 percent of growth layer completed by July 18	1955	Jan.-Feb.--Below to much below Mar.--Slightly above Apr.-July--Below Aug.-Sept.--Above	Annual: Next to least in 4-year period, 1955-58 Jan.--Above normal Feb.-May--Below to much below June-Aug.--Above June--More than 5 times normal Sept.-Oct.--Much below	Became abundant in mid-June to 12-inch depth, and remained so until late August if plaster blocks had reached equilibrium

[1] Because temperature records are not kept at Walnut Canyon and because precipitation records were begun in late 1950, records fr Flagstaff Airport are combined here with Walnut Canyon information on tree growth.

)56 was the lowest of the 4 years, whereas at of 1957 was the highest. The year 1958)es not give a very clear picture. It may ıve been that some plaster blocks had be-)me weakened. Fall-winter precipitation was gh; soil moisture penetrated more deeply ıt decreased earlier than in 1957 and then as replenished early in August.

In summary, temperature variations did)t appear to have a direct influence on thick- ɜss of growth layers. Information from the 4 ɜars of record suggests that the thickness of growth layer increased the longer soil oisture remained in good supply going into e early summer and/or the sooner the ıpply was replenished during the summer.

SUMMARY

Interpretations, with only 4 years of read- ıgs, are only indicative. The following points ay be mentioned:

Available soil moisture fluctuated widely in the root zone; it commonly showed more than one cycle a year, especially at the lower forest border.

The records suggest that soil-moisture fluctuations were greater and occurred more rapidly in a dry year and at the drier of the two stations.

Infiltration and percolation occurred in a matter of hours and days rather than of weeks and months.

Without constant and, in summer, abundant replenishment, soil moisture was removed from the root zone rather rapidly.

The soil-moisture régime showed a decided diversity from year to year, and a lack of coincidence in details between the two stations--one in the forest interior, and the other at the lower border of the ponderosa pine zone.

The data and graphs apparently testify to continuous physiological activity that removed soil moisture throughout the year--growth part of the time, transpiration and evaporation all the time.

7. Diameter growth at Walnut Canyon was commonly more advanced than at Fort Valley at any particular time during the growing season.

8. Temperatures within the growing season did not appear to have had a direct and major effect upon amount of tree growth.

9. Of the precipitation periods examined, July-August rainfall seemed to have considerable influence on diameter growth.

10. Thickness of growth layers apparently increased the longer soil moisture remained in good supply going into the early summer and/or the sooner the supply was replenished during the summer.

In general, the study emphasized the desirability of obtaining continuous soil-moisture records for a more extended period, with associated constant check of tree growth.

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Table 3.--Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorded at each station, 1955-58

FORT VALLEY — WALNUT CANYON

Date		Available soil moisture: Depth of meter, in inches											Precipitation		Date	Available soil moisture: Depth of meter, in inches							Precipitation	
		4	8	12	18	24	36	48	60	70	84	96	Date	Amount		4	8	12	18	24	36	42	Date	Amount
		Percent												Inches		Percent								Inches
1955																								
May	27	74	77	77	75	57	0	0	0	0	3	17	26	0.11	31	0	8	9	1	0	0	16	May	.65
	30	72	77	79	76	56	0	0	0	0	2	17												
June	3	63	74	77	73	51	0	0	0	0	2	17	9	T	3	0	5	6	0	0	0	16		
	4	60	73	76	72	47	0	0	0	0	2	17	10	T	10	0	4	5	2	0	1	16		
	13	76	79	77	76	75	0	0	0	0	2	17	13	2.49	13	83	3	4	1	1	2	16	12	.15
	14	75	78	77	74	73	0	0	0	0	2	17	14	1.20	15	89	87	16	1	1	2	16	13	3.05
	15	77	79	77	75	73	0	0	0	0	2	17			16	85	88	30	2	1	2	16	14	.18
	16	77	79	78	75	74	0	0	0	0	2	17			17	89	89	34	1	1	2	16		
	17	78	79	78	75	74	0	0	0	0	2	17			18	90	89	42	1	1	2	16		
	21	80	81	80	78	77	10	0	0	0	2	17			19	89	90	47	1	1	2	16		
	22	81	82	80	79	77	12	0	0	0	2	17			20	91	91	53	1	1	2	16		
	23	82	82	81	79	77	13	0	0	0	3	17			21	91	92	58	1	1	2	16		
	24	82	82	81	79	78	17	0	0	0	2	17			22	92	92	63	1	1	2	16		
	27	82	82	82	80	79	16	0	0	0	2	17			23	92	92	71	1	1	2	16		
	28	82	82	81	80	79	17	0	0	0	2	17			24	90	90	75	1	1	2	16		
	29	81	81	81	80	79	17	0	0	0	3	17			25	90	90	78	1	1	3	16		
	30	81	82	81	80	79	17	0	0	0	3	17			26	90	91	78	2	1	2	16		
															27	89	91	80	2	1	1	16		
															28	88	91	80	2	1	1	16		
															29	86	90	80	1	1	2	16		
															30	84	90	80	–	1	2	16		
July	1	81	81	81	80	79	17	0	0	0	3	17			1	82	89	80	–	1	2	16		
	5	82	82	82	81	79	17	0	0	0	4	17			2	81	89	80	–	1	2	16		
	6	82	82	82	81	79	17	0	0	0	3	17			3	74	86	80	–	1	2	16		
	7	81	82	82	82	79	17	0	0	0	3	17			4	68	85	77	–	1	2	16		
	9	81	82	82	81	77	16	0	0	0	5	17			5	62	84	78	–	0	2	16		
	12	81	82	82	80	75	15	0	0	0	4	17	13	.03	6	56	83	76	–	0	2	16		
	14	80	82	82	80	73	15	0	0	0	5	17	16	.27	7	50	81	75	–	0	2	16		
	18	83	83	82	80	69	14	0	0	0	5	17	17	.77	8	46	79	75	–	0	2	16		
	19	83	83	82	80	65	13	0	0	0	5	18	18	.15	9	40	79	74	–	0	2	16		
	20	83	83	82	80	63	13	0	0	0	5	18	20	.06	10	34	71	72	–	0	2	16		
	21	83	83	82	79	62	12	0	0	0	5	17	21	.08	11	28	66	70	–	0	2	16		
	22	83	82	82	78	60	12	0	0	0	5	17	22	.03	12	23	64	67	4	0	2	16		
	25	85	84	83	80	55	12	0	0	0	5	18	23	.11	13	18	59	64	5	0	2	16		
	26	85	84	83	81	53	11	0	0	0	5	18	24	.05	14	17	56	60	5	0	2	16		
	27	85	84	82	81	52	11	0	0	0	5	18	25	1.03	15	18	61	58	5	0	4	16	15	1.29
	28	85	84	83	81	50	11	0	0	0	5	18	26	.16	16	41	81	71	5	2	2	16	16	.25
	29	85	84	83	82	49	11	0	0	0	5	18			17	61	87	78	5	0	2	16	17	.46
													29	.50	18	85	90	82	7	1	2	17		
															19	85	90	84	7	1	2	17		
															20	86	91	85	8	1	2	17	20	.08
															21	87	92	85	9	1	2	17		
															22	88	92	85	10	1	2	17	22	.01
															23	88	92	85	10	1	2	17	23	.06
															24	85	91	85	11	1	2	17	24	.20
															25	85	90	85	11	1	2	17	25	.27

Table 3. --Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation records at each station, 1955-58 (continued)

FORT VALLEY

Date	Available soil moisture: Depth of meter, in inches: 4	8	12	18	24	36	48	60	70	84	96	Precipitation: Date	Amount
	Percent												Inches
1955 July (cont'd)													
Aug. 1	85	84	83	81	45	10	0	0	0	5	18	1	.11
												2	T
3	87	86	85	82	44	10	0	0	0	5	18	3	.51
4	86	85	84	82	42	10	0	0	0	5	18	4	.03
5	86	85	84	81	40	10	0	0	0	5	18		
												6	.07
												7	.25
8	87	86	84	80	36	9	0	0	0	5	18	8	.42
9	88	86	85	83	35	9	0	0	0	5	18	9	.57
10	87	86	85	83	33	9	0	0	0	5	18	10	.12
11	88	87	85	83	32	9	0	0	0	5	18	11	.44
12	88	87	85	82	31	9	0	0	0	5	18	12	T
												13	.64
15	88	87	85	83	29	8	0	0	0	6	18	15	1.14
16	89	87	85	83	36	8	0	0	0	5	18	16	.01
17	89	87	85	83	79	7	0	0	0	5	18	17	.94
18	89	87	85	83	80	7	0	0	0	5	18		
19	89	87	85	83	80	6	0	0	0	5	18		
												20	.52
												21	T
22	89	87	85	83	82	8	0	0	0	5	18		
23	89	87	85	83	82	10	0	0	0	5	18		
24	89	80	85	84	82	10	0	0	0	5	18	24	1.28
25	89	82	85	83	82	76	0	0	0	5	19		
26	89	80	85	83	82	77	0	0	0	5	19		
29	89	87	84	83	82	80	0	0	0	5	19		
30	89	86	82	84	82	80	0	0	0	5	19		
31	89	87	81	84	82	80	0	0	0	5	19		
Sept. 1	89	88	76	84	82	81	0	0	0	5	19		
2	89	87	76	84	82	81	0	0	0	5	19		
7	87	86	85	84	82	82	0	0	0	6	19		
9	87	86	84	84	82	82	2	0	0	6	19		
12	86	86	83	84	82	81	3	0	0	6	19		
16	85	85	81	83	82	77	4	0	0	6	19		
												17	T
19	84	85	82	84	82	70	3	0	0	6	19		
23	82	84	60	83	81	58	3	0	0	6	19		
Oct.												4	.04
10	40	49	55	58	49	18	0	0	0	5	19	10	.05
19	22	30	42	38	20	11	0	0	0	4	19		
24	17	20	30	21	15	7	0	0	0	3	19		
Nov.												13	.18
												14	.19
												15	.42
												16	T
												18	.26
												22	.27
Dec.												2	.90
												3	.15
												4	,10
												7	T

WALNUT CANYON

Date	Available soil moisture: Depth of meter, in inches: 4	8	12	18	24	36	42	Precipitation: Date	Amount
	Percent								Inches
1955 July (cont'd) 26	88	90	85	11	1	2	17		
27	88	90	84	12	1	2	17		
28	89	90	83	12	1	2	17		
29	87	89	84	12	1	2	17	29	.01
30	85	89	82	12	1	2	17	30	.26
31	85	88	82	12	1	2	17	31	.09
Aug. 1	84	87	82	13	1	2	17		
2	83	85	81	13	1	2	17		
3	81	84	80	13	1	3	17	3	.05
4	78	83	78	13	1	3	17	4	.01
5	72	81	75	13	1	3	17	5	.26
6	66	78	72	13	1	3	17	6	.98
7	81	82	72	13	1	3	17	7	.63
8	89	91	75	13	1	3	17	8	.25
9	90	92	79	13	1	3	17		
10	91	94	82	13	1	3	17		
11	91	94	83	13	1	3	17		
12	91	95	85	13	1	3	18	12	.29
13	92	94	85	13	1	3	17		
14	92	95	85	13	1	4	18	14	.02
15	93	95	85	13	1	4	18		
16	92	95	86	14	1	4	18	16	.14
17	93	95	85	14	1	4	18		
18	92	95	85	14	1	4	18		
19	90	93	84	14	1	4	18	19	.28
20	87	90	82	15	2	4	18		
21	92	95	85	15	2	4	18		
22	92	95	85	14	2	4	18		
23	91	95	85	14	2	4	18	23	.04
24	91	94	84	14	2	4	18	24	.16
25	90	94	84	14	2	4	18		
26	88	92	83	14	2	4	18		
27	84	91	82	14	2	4	18	27	.06
28	80	89	81	14	2	4	18	28	.01
29	74	86	78	14	2	4	18		
30	65	81	73	14	3	5	19		
31	59	78	69	14	3	5	19		
Sept. 2	45	67	57	13	4	5	18		
4	28	55	47	13	4	5	19		
5	20	49	41	13	4	5	19	5	.07
6	18	43	32	11	4	5	19		
7	15	37	25	11	4	5	19		
8	12	31	23	10	4	5	19		
9	11	25	19	10	4	5	19		
10	10	20	15	10	3	5	18		
11	8	18	13	8	3	5	18		
13	5	15	9	7	4	5	18		
14	3	13	6	6	3	5	18		
22	1	1	1	2	2	4	17		
29	0	0	0	1	1	4	15		
Oct.								4	.05
8	0	0	0	0	1	4	13		
13	0	0	0	0	1	4	12		
20	0	0	0	0	1	3	10		
28	0	0	0	0	0	3	8		
Nov. 4	0	0	0	0	0	3	7		
13	0	0	0	0	0	3	7	13	.62
								14	.33
15	1	-	-	-	-	3	7	15	.02
								22	.28
24	41	0	0	0	0	3	9		
Dec. 1	55	0	0	0	0	3	10		
								2	.98
29	76	37	1	0	0	4	11		

able 3.--Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorded at each station, 1955-58 (continued)

FORT VALLEY

Date	Available soil moisture: Depth of meter, in inches 4	8	12	18	24	36	48	60	70	84	96	Precipitation: Date	Amount
	---------- Percent ----------												Inches
956													
an.												16	T
												17	.48
												20	.05
												21	.25
												22	T
												23	T
												24	.22
												25	T
												26	.05
												27	.38
												28	.45
												29	.62
Feb.												1	.22
												7	T
												8	.40
												9	.04
												16	.10
												17	.20
												19	T
												24	.04
Mar.												7	.09
												12	.30
												13	.08
												15	T
30	75	73	61	71	66	9	0	0	0	2	14		
Apr.												1	.05
6	77	75	62	72	64	7	0	0	0	0	14	2	.10
13	77	75	62	72	60	5	0	0	0	0	14	13	.12
												14	.30
												16	T
												17	.20
												18	T
20	77	75	62	69	54	4	0	0	0	2	15	19	.27
												21	.08
												26	T
27	79	77	63	68	50	3	0	0	0	2	15	27	T
May 4	80	78	63	66	46	2	0	0	0	2	15		
11	80	76	61	62	39	2	0	0	0	2	16		
14	79	76	60	59	35	2	0	0	0	3	16		
												20	.06
												21	T
												22	.11
25	74	68	60	46	18	0	0	0	0	2	15		
June 1	57	50	50	32	11	0	0	0	0	2	16		
8	37	29	37	16	6	0	0	0	0	2	15		
15	17	13	16	6	2	0	0	0	0	2	15		

WALNUT CANYON

Date	Available soil moisture: Depth of meter, in inches 4	8	12	18	24	36	42	Precipitation: Date	Amount
	----- Percent -----								Inches
16	52	39	0	0	0	3	11	16	.10
								17	.06
								20	.01
								21	.13
22	45	33	1	0	0	1	10	22	T
								23	.10
25	45	31	1	0	0	2	11	25	.05
								26	.06
								27	.20
28	48	30	1	0	0	1	10	28	.30
								29	.23
								31	.23
								1	.02
								8	T
								9	.83
								16	.31
18	78	59	2	0	0	1	12		
								23	.01
29	80	81	27	0	0	2	12		
2	81	82	35	0	0	2	12		
3	81	82	38	0	0	2	12		
5	84	84	46	0	0	2	12	6	.02
7	83	84	50	0	0	2	12	7	T
9	81	83	55	1	0	2	12		
10	82	84	58	0	0	2	12	11	.05
12	82	85	64	0	0	2	12	12	.24
13	81	83	64	0	0	2	12	14	.01
15	81	83	66	0	0	2	12		
16	82	83	69	0	0	2	12		
17	80	82	71	0	0	2	13		
18	83	84	72	0	0	2	13		
24	82	85	75	0	0	2	13		
26	83	84	75	0	0	2	13		
30	76	82	73	0	0	2	13		
1	67	79	71	0	0	2	13	1	.01
6	60	68	64	0	0	2	14	2	.05
7	54	65	63	0	0	2	14		
8	53	63	61	0	0	3	14		
9	49	61	60	0	0	3	14		
11	43	57	57	0	0	3	14	14	.37
16	29	47	47	0	0	4	13	15	.14
17	26	45	45	0	0	4	13	17	T
20	28	39	38	0	0	5	14	18	.26
21	28	38	38	0	0	5	14	20	.04
22	29	36	35	0	0	5	14		
23	30	36	33	0	0	4	14		
24	28	34	31	0	0	5	14		
25	28	33	28	0	0	5	15		
26	26	35	26	0	0	5	15		
28	23	38	20	0	0	5	14	27	.05
29	22	29	17	0	0	5	14		
30	21	26	17	0	0	5	15		
1	20	23	16	0	0	4	15		
2	18	21	15	0	0	4	15		
3	17	20	15	0	0	4	15		
5	13	17	11	0	0	4	14		
6	12	17	11	0	0	4	14		
7	11	16	10	0	0	4	14		
9	6	13	6	0	0	4	14		
15	0	4	1	0	0	4	12		
22	0	0	0	0	0	2	12	19	.12
29	0	0	0	0	0	1	9		
6	0	0	0	0	0	1	6		
12	0	0	0	0	0	1	5		
20	0	0	0	0	0	1	4		

Table 3.--Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorde at each station, 1955-58 (continued)

	FORT VALLEY													WALNUT CANYON									
	Available soil moisture											Precipitation		Available soil moisture								Precipitatio	
Date	Depth of meter, in inches													Date	Depth of meter, in inches								
	4	8	12	18	24	36	48	60	70	84	96	Date	Amount		4	8	12	18	24	36	42	Date	Amoun
1956	Percent												Inches		Percent								Inches
June 22	6	6	3	0	0	0	0	0	0	0	14	28	.24	27	0	0	0	0	0	1	3	28	.17
(cont'd) 29	4	4	2	0	0	0	0	0	0	0	14	30	1.65	30	20	0	0	0	0	1	3	29-30	1.27
July 3	22	12	2	0	0	0	0	0	0	0	13	1	T	2	75	0	0	0	0	1	5		
5	22	13	3	0	0	0	0	0	0	0	13			3	65	0	0	0	0	1	5		
6	23	14	5	0	0	0	0	0	0	0	14			4	62	0	0	0	0	1	5		
9	20	15	4	0	0	0	0	0	0	0	14			5	59	0	0	0	0	0	6		
10	20	14	4	0	0	0	0	0	0	0	13			6	57	0	0	0	0	0	6		
11	19	14	4	0	0	0	0	0	0	0	13			7	53	0	0	0	0	1	6		
12	19	14	3	0	0	0	0	0	0	0	13	12	T	8	49	0	0	0	0	1	6		
13	18	13	3	0	0	0	0	0	0	0	13	13	.20	10	40	0	0	0	0	1	5	12-13	.24
												14	T	14	12	0	0	0	0	1	4	14	.30
												15	T	15	10	0	0	0	0	1	4		
16	17	11	2	0	0	0	0	0	0	0	13	16	.07	17	4	0	0	0	0	1	3		
17	16	11	2	0	0	0	0	0	0	0	13	18	.13	19	3	0	0	0	0	0	3	19	.02
18	12	10	2	0	0	0	0	0	0	0	13	19	.32	21	1	0	0	0	0	0	3	21	.42
19	14	9	0	0	0	0	0	0	0	0	13	20	T	22	1	0	0	0	0	1	3		
20	13	9	2	0	0	0	0	0	0	0	13	21	.12	24	2	0	0	0	0	0	3		
												22	.20	25	2	0	0	0	0	0	3		
												23	T	26	2	0	0	0	0	0	3	26	.24
23	11	8	0	0	0	0	0	0	0	0	13	25	.23	28	6	0	0	0	0	0	5	27	.57
24	11	7	0	0	0	0	0	0	0	0	13	26	.49	29	11	0	0	0	0	0	6	28	T
26	9	5	0	0	0	0	0	0	0	0	12	27	T	30	12	0	0	0	0	0	8	29	.23
30	75	34	72	65	0	0	0	0	0	0	12	28	.07									30	.13
31	76	43	72	69	0	0	0	0	0	0	12	29	.69										
												30	.09										
Aug. 2	79	48	71	66	0	0	0	0	0	0	12	2	.38									1	.32
4	36	47	42	6	0	0	0	0	0	0	12	11	T	4	22	0	0	0	0	0	8	11	.30
6	74	51	67	57	0	0	0	0	0	0	12	12	.12	13	9	0	0	0	0	0	4	14	.15
9	68	51	62	49	0	0	0	0	0	0	12	13	.44	15	3	0	0	0	0	0	4	15	.07
13	55	50	55	37	0	0	0	0	0	0	12	14	.16	17	1	0	0	0	0	0	4	17	.16
16	48	47	50	24	0	0	0	0	0	0	12	15	.20									21	.19
												16	.02	24	0	0	0	0	0	0	2	24	.04
20	46	50	49	13	0	0	0	0	0	0	12	17	.28										
												18	.05										
22	42	49	42	10	0	0	0	0	0	0	12	19	.04										
28	19	38	29	2	0	0	0	0	0	0	12	22	.11										
31	13	22	16	0	0	0	0	0	0	0	12	23	T										
Sept. 4	7	12	4	0	0	0	0	0	0	0	12			6	0	0	0	0	0	0	0	30	T
7	3	6	0	0	0	0	0	0	0	0	12												
14	0	2	0	0	0	0	0	0	0	0	12												
21	0	0	0	0	0	0	0	0	0	0	12												
28	0	0	0	0	0	0	0	0	0	0	12	29	T										
Oct.												2	.03	4	0	0	0	0	0	0	0		
												3	.16	23	0	0	0	0	0	0	0	24	.29
8	0	0	0	0	0	0	0	0	0	0	11	7	.09	30	0	0	0	0	0	0	0	29	.09
12	0	0	0	0	0	0	0	0	0	0	11	24	.17										
19	0	0	0	0	0	0	0	0	0	0	11	29	.37										
Nov. 16	0	0	0	0	0	0	0	0	0	0	9	1	.05										
23	0	0	0	0	0	0	0	0	0	0	10	2	T										
30	0	0	0	0	0	0	0	0	0	0	9												
Dec. 7	0	0	0	0	0	0	0	0	0	0	8	5	T	13	0	0	0	0	0	0	0	7	.42
14	0	0	0	0	0	0	0	0	0	0	8	7	.13										
21	0	0	0	0	0	0	0	0	0	0	8	8	.41										
1957 Jan.												4	.20	7	0	0	0	0	0	0	0	5	.42
5	0	0	0	0	0	0	0	0	0	0	7	5	.31	9	75	0	0	0	0	0	0	7	.03
												6	.13	10	75	0	0	0	0	0	0	8	1.72
												8	1.28	12	75	22	0	0	0	0	0	9	.88
												9	.69	13	77	35	0	0	0	0	0	13	.13
												10	.16	15	77	58	11	0	0	0	0		
11	64	63	53	63	0	0	0	0	0	0	6	11	.23	16	75	74	14	0	0	0	0		
												13	T	18	75	75	22	0	0	0	0		
												14	.39									21	.50
18	69	67	58	68	45	0	0	0	0	0	6	21	.23									25	.40
												22	.11									26	.60

Table 3.--Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorded at each station, 1955-58 (continued)

FORT VALLEY

Date		Available soil moisture: Depth of meter, in inches 4	8	12	18	24	36	48	60	70	84	96	Precipitation Date	Amount
		Percent												Inches
1957														
													24	T
Jan. (cont'd)	25	70	68	55	69	58	0	0	0	0	0	6	25	.07
													26	.34
													27	.87
													28	.60
													29	.24
													30	.32
													31	T
Feb.	18	72	71	63	70	65	64	0	0	0	0	7	18	.18
													19	.17
													20	.09
													21	.02
													22	T
	25	73	72	54	71	70	68	52	0	0	0	8	24	.60
Mar.													1	.14
													2	.52
													3	.04
	4	74	72	64	72	71	71	58	0	0	0	8	4	T
													6	.04
	11	75	73	62	72	72	71	61	0	0	0	9	10	.05
	18	75	73	65	73	67	72	62	0	0	0	8	17	.26
													20	.13
													21	.05
													22	.08
	25	74	71	63	72	71	72	61	3	0	0	10	31	T
Apr.	5	75	72	64	72	71	72	61	5	0	0	9	2	.22
	12	77	73	65	74	72	73	61	6	0	0	10	3	.19
	19	76	73	64	74	72	72	60	7	0	0	10	19	T
													22	.17
													23	.27
													24	.11
													25	.06
	26	76	70	64	73	72	72	58	6	0	0	10	26	T
May	6	78	73	65	74	72	73	54	5	0	0	10	7	.27
													11	.29
													12	.38
	13	78	74	64	74	73	73	51	4	0	0	11	13	.04
													15	.11
													16	.16
													17	T
													18	T
													19	T
	20	79	73	63	74	72	73	47	4	0	0	11	20	.45
													21	.10
													22	.14
													23	.05
	27	78	74	63	74	73	73	44	4	0	0	11	24	.13
June	3	81	77	63	75	75	75	40	4	0	T	12	5	T
													6	.02
	11	81	78	62	72	74	73	34	3	0	T	11	10	.36
	17	85	82	66	75	79	78	31	6	T	4	13	11	.85
	24	85	82	60	71	75	6	26	5	T	4	13	26	.11
July	1	72	74	56	62	69	7	21	6	2	5	13	5	T
													6	.02
													7	.03
	8	44	53	42	52	61	7	17	6	1	5	14	9	.02
													10	T
													14	.48
	16	16	27	26	29	41	7	13	6	2	5	13	16	.02
													17	.20
													18	.57
	19	14	26	26	20	31	7	12	5	2	6	13	19	.11
													20	.36
	22	15	27	19	15	20	7	12	5	2	5	13	24	.11
													25	.04

WALNUT CANYON

Month	Date	Available soil moisture: Depth of meter, in inches 4	8	12	18	24	36	42	Precipitation Date	Amount
		Percent								Inches
1957 Jan. (cont'd)									27	1.31
									28	.52
									29	.02
									30	.40
Feb.	5	85	86	86	0	0	0	0		
	8	85	86	86	0	0	0	0		
	11	86	85	87	75	76	1	0		
	14	86	85	84	80	80	75	5		
	19	82	85	85	82	82	76	9	18	.24
	23	82	85	85	84	84	79	12	19	.02
	28	82	86	85	84	85	78	23	23	.25
Mar.									1	.94
	3	82	85	85	85	85	76	32		
	6	82	85	85	85	85	78	38		
	10	82	85	86	85	85	78	45		
	14	82	85	85	85	85	80	48		
	18	82	85	85	85	85	80	52	17	T
	21	82	86	86	86	86	78	55	19	.07
	28	72	86	85	85	85	76	56	20	.55
	31	82	86	86	85	85	75	57	22	.10
Apr.									2	.29
	11	82	85	85	85	85	72	55		
	18	75	81	85	85	85	68	55		
	23	62	70	80	80	82	65	55	22	.34
	28	56	60	71	78	80	60	52		
May	5	42	48	56	72	76	56	52	6	.10
									7	.26
	10	27	35	45	67	75	52	52	10	.03
									11	.45
									12	.37
									13	.02
									14	.26
									19	.25
	21	55	35	32	55	64	46	49	21	.14
									23	.14
	31	62	36	25	46	60	41	47		
June									10	1.00
									11	.10
	12	29	15	12	36	50	32	45		
	24	17	12	9	23	41	26	38		
July	1	2	5	4	15	32	21	33	7	T
	8	0	T	T	11	22	17	28	8	.20
									9	.35
	10	0	T	T	10	19	17	28	10	.02
	16	0	0	T	5	13	13	22	17	.15
	19	0	0	T	4	12	12	20	19	.18
	23	0	0	0	2	11	11	17		
									26	.25
	30	0	0	0	T	8	9	15	27	.10

Table 3. --Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorde at each station, 1955-58 (continued)

FORT VALLEY														WALNUT CANYON									
Date	Available soil moisture: Depth of meter, in inches											Precipitation		Date	Available soil moisture: Depth of meter, in inches							Precipitation	
	4	8	12	18	24	36	48	60	70	84	96	Date	Amount		4	8	12	18	24	36	42	Date	Amount
1957	Percent												Inches		Percent								Inches
July 26	14	21	13	12	14	6	11	4	2	5	13	26	.37										
(cont'd)												27	.31										
												28	.05										
29	16	19	13	11	13	5	10	5	2	5	15	29	.16										
Aug.												3	.42									4	.43
												4	.03									5	.18
5	13	0	42	8	9	5	7	4	2	5	13	5	.30	6	0	0	0	0	4	6	14	6	.06
												6	.45	8	1	0	0	0	4	6	13		
												11	.10	13	0	0	0	0	T	5	12	10	.05
13	15	17	27	5	6	4	5	4	T	5	14	13	.02									15	.21
												14	T	20	0	0	0	0	0	3	12	24	.64
												19	T									25	.03
20	8	10	5	3	4	2	4	2	T	4	11	20	.09									26	.26
												25	.45	27	0	0	0	0	T	3	11	27	.03
												26	.16									29	.05
27	17	0	3	1	1	1	4	3	T	4	14	27	.22									30	.21
												29	.07										
												30	.09										
												31	.02										
Sept. 5	7	0	T	0	0	0	T	T	0	2	14			4	0	0	0	0	0	3	12		
11	T	0	0	0	0	T	T	T	T	4	14	10	T	9	0	0	0	0	0	4	7		
17	0	0	0	T	T	T	2	2	T	4	15			16	0	0	0	0	T	5	7		
23	0	0	0	0	0	T	2	T	T	3	15			23	0	0	0	0	0	5	6		
														30	0	0	0	0	0	3	5		
Oct. 2	0	0	0	0	0	T	T	T	T	3	13	11	.55	7	0	0	0	0	0	T	3		
7	0	0	0	0	0	0	0	0	0	T	11	12	.57									11	.27
												13	.71									12	1.23
14	76	33	59	81	0	0	0	0	0	0	9	14	.12	14	0	0	0	0	0	3	9		
												15	.03	16	7	0	0	0	0	3	11		
16	76	37	58	80	0	0	0	0	0	T	10	16	.03	18	14	0	0	0	0	3	13		
												17	T									19	.24
												20	.19									20	.20
21	70	38	56	70	0	0	0	0	0	0	8	21	.22	21	18	0	0	0	0	3	14	21	.22
												22	.65	25	29	0	0	0	0	4	14		
28	81	46	77	66	0	0	0	0	0	T	7	28	T									28	.29
												29	.29	29	36	0	0	0	0	4	14	29	.03
31	83	0	80	64	0	0	0	0	0	0	9	31	.60									31	1.10
Nov.												1	.39	1	53	0	0	0	0	4	14	1	.21
												2	.13									2	.28
												3	1.26									3	.94
4	83	53	81	79	81	0	0	0	0	0	8	4	.80	4	80	80	80	0	0	3	14	4	.28
												5	T									6	.19
												6	.38	7	76	82	81	0	0	4	15		
												7	.08	15	79	84	83	84	33	6	15		
												12	.03									16	.30
												15	T	20	76	83	83	85	81	5	16		
												16	.52										
												17	.22										
												22	T										
Dec. 3	80	0	77	79	79	8	0	0	0	0	9	5	.12	3	74	82	83	86	83	4	15		
												6	.30									5	.15
												16	.36	10	75	82	84	85	84	8	16		
												17	T									15	.08
												18	.04									18	.10
												19	.03	24	74	82	83	84	83	17	16		
1958																							
Jan.												3	T									3	.13
												4	.03	17	72	80	80	82	81	20	16		
												5	T									27	.15
												11	T										
14	76	71	75	76	75	7	T	T	2	3	10	14	T										
												19	T										
												20	T										
												22	.03										
												25	.04										
												27	.32										

Table 3. --Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorded at each station, 1955-58 (continued)

FORT VALLEY														WALNUT CANYON									
Available soil moisture												Precipitation		Available soil moisture								Precipitation	
Date	Depth of meter, in inches													Date	Depth of meter, in inches								
	4	8	12	18	24	36	48	60	70	84	96	Date	Amount		4	8	12	18	24	36	42	Date	Amount
1958	Percent												Inches		Percent								Inches
Jan. (cont'd)												31	T										
Feb.												4	.53									3	.12
												5	1.00									4	1.12
												6	T									5	.02
												9	T									9	.01
												10	.05	12	73	81	82	83	80	20	17		
												13	T									13	.05
												14	.13									20	.06
												21	.09									23	.13
												23	T									25	.56
												24	.10									26	.06
												26	.73										
												27	T										
Mar.												2	T									3	.26
												3	T									4	.05
												4	.18									6	.10
												5	T									7	.28
												6	.04									9	.20
												7	.68									11	.05
												9	.30									12	.02
												11	T									13	.16
												12	.21									16	.17
												13	.15									17	.22
												14	.12									22	.88
												16	.32									28	.29
												17	.56										
												18	.04										
												21	T										
												22	.75										
												23	.33										
												24	T										
												25	T										
												28	.34										
												29	.08										
Apr.												2	.68									2	.44
												3	T									3	.10
												4	.54									4	.66
												5	.30									5	.14
												7	T									7	T
												8	.08									8	.10
												9	T										
28	74	70	54	71	72	10	68	69	70	73	76	17	.13										
May												3	.25									2	.03
5	81	76	79	78	76	7	74	81	75	79	83	11	.11									11	.43
												12	.33									30	T
21	75	72	68	75	74	10	70	70	70	74	77	21	.10										
												31	.06										
June 12	48	43	40	65	73	13	68	70	70	75	79	16	T	17	0	0	0	0	24	20	58		
												22	.38									21	.20
26	15	14	10	44	62	10	62	65	70	76	80	23	T	23	0	0	0	0	12	12	50		
												30	T										
July 14	10	5	6	12	15	10	45	55	63	74	80	18	T	7	0	0	0	0	1	6	20	6	.04
												23	T	17	0	0	0	0	0	3	10		
												24	.58									23	.17
												25	T									24	.03
												26	.08									25	.01
												27	.06									26	.09
												28	.03									29	.26
												29	T	31	0	0	0	0	0	0	5	30	.10
												30	.15										
												31	.02										
Aug.												2	T									2	.03
												3	.22									3	.17
4	5	2	2	3	5	6	18	28	43	72	77	4	.06									4	.07

Table 3.--Percentage of available soil moisture from readings of the Bouyoucos soil-moisture meters, and precipitation recorded at each station, 1955-58 (continued)

FORT VALLEY

Month	Date	Available soil moisture — Depth of meter, in inches: 4	8	12	18	24	36	48	60	70	84	96	Precipitation: Date	Amount
1958		Percent												Inches
Aug. (cont'd)													5	.11
													6	.54
													7	.31
													10	.49
	11	15	14	56	67	10	8	14	21	37	66	76	11	.16
													13	.07
													14	.01
													15	.02
													17	.75
	18	17	18	42	58	8	8	12	17	31	63	72	18	.02
													19	.01
													20	.06
													21	.35
													22	.04
													23	T
	25	24	27	56	69	9	8	12	16	27	62	75	24	.70
													28	.16
													29	T
													30	.01
Sept.													1	T
	2	30	32	48	67	9	7	11	15	24	62	73	3	T
													4	1.73
													5	.32
													7	.04
	8	31	34	55	67	66	6	10	14	21	56	64	8	1.15
													9	T
													10	1.38
													12	.27
	15	65	62	55	64	63	12	37	14	20	54	61	13	.69
	22	72	74	65	74	74	12	48	15	20	58	71	23	.65
													24	.28
													25	.09
													27	.61
													28	.66
	29	72	77	64	69	70	50	44	16	20	54	71	29	.48
Oct.	6	67	66	65	67	64	51	48	15	18	51	62	6	.20
													12	.16
	13	77	77	75	79	77	55	50	16	18	56	72	13	T
	21	70	66	57	73	72	51	42	14	18	53	68	24	.07
													25	.32
	27	61	60	52	64	63	42	33	14	17	49	63	26	T
													30	.02
Nov.													11	T
	12	56	53	47	57	52	18	18	13	17	49	69	12	.58
													16	.50
													17	.24
													24	T
													27	.06
Dec.													29	.05

WALNUT CANYON

Month	Date	Available soil moisture — Depth of meter, in inches: 4	8	12	18	24	36	42	Precipitation: Date	Amount
1958		Percent								Inches
Aug. (cont'd)									5	.40
									6	.03
	8	0	0	0	0	0	0	12	7	.16
									11	.27
									13	.04
									17	1.56
									19	.09
									21	.55
									22	.05
									27	.11
									29	.02
Sept.									1	.07
									2	.32
									3	.29
	5	56	28	3	0	0	8	12	4	.47
									7	.05
									8	.20
									11	.14
									12	1.03
									13	.23
									14	.04
	23	70	56	12	0	0	10	12	23	.16
									24	.63
									26	.08
									27	.84
									28	.79
	29	82	89	85	0	0	9	15	29	.42
Oct.	2	82	90	85	0	0	10	15	5	.07
	8	82	90	88	10	1	10	13	10	.29
	15	81	85	88	12	2	9	13	23	.02
	20	70	72	80	12	4	9	13	24	.19
									25	.20
									29	.15
									30	.11
Nov.	4	51	38	53	12	4	9	17		
	11	45	25	42	9	2	9	18	11	T
									12	.25
									15	.15
									16	.82
									17	T
Dec.	13	55	52	28	4	4	8	18		
	16	53	50	25	2	2	8	18	28	.02

Glock, Waldo S., Gaines, Edward M., and Agerter, Sharlene R. 1964. Soil-moisture fluctuations under two ponderosa pine stands in northern Arizona. U. S. Forest Serv. Res. Paper RM-9, 34 pp., illus.

Four years of readings showed wide variation in the root zone, commonly more than one cycle per year. Fluctuations were greater and more rapid in dry years; infiltration and percolation occurred within hours or days.

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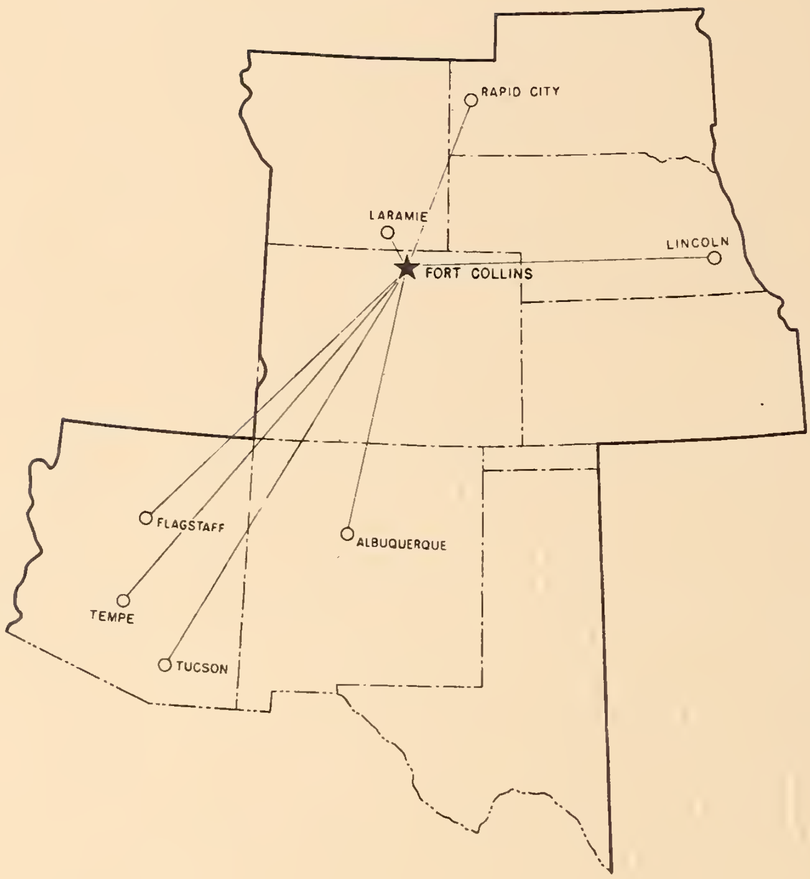
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FORT COLLINS
FLAGSTAFF
ALBUQUERQUE
TEMPE
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